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Energy Conscious Planning and Programming for New Facilities

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Improved Planning and Programming for Energy Efficient New Army Facilities

by
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This report describes research on ways to place more emphasis on energy conservation in the early stages of Army construction planning. Decisions made then can have substantial effects on the energy use characteristics of the entire project. Conservation strategies are currently considered in the late design stages, where they can be useful, but the cleverest design details cannot compensate for oversights that have been frozen in the project specifications.

The report makes suggestions for incorporating energy issues in the current Military Construction, Army (MCA) process (in Department of Defense [DD] Form 1391, [Department of the Army (DA) Forms 5020-R and 5021-R]). A new method for selecting conservation strategies is discussed, along with methods for calculating energy savings. The strategy selection method has been implemented in an expert system. A set of energy conservation options was field-tested in a Technology Transfer Test Bed (T^3B) program. Recommendations have been made for changes to Army Regulation (AR) 415-15, *Military Construction, Army*.

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FOREWORD

This work was performed for the Directorate of Engineering and Construction, Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 4A162781AT45, "Energy and Energy Conservation"; Task Area A, "New Construction Energy Design"; Work Unit 008, "Energy Conscious Planning and Programming for New Facilities." Mr. J. McCarty, CEEC-EE, was the HQUSACE Technical Monitor. Mr. D. Lyon, Training and Doctrine Command (TRADOC), ATEN-FE, was the Field Monitor.

The work was conducted by the Energy Systems Division, U.S. Army Construction Engineering Research Laboratory (USA-CERL-ES). Dr. G. R. Williamson is Chief, ES. Appreciation is expressed to Cheol Kim, formerly of USA-CERL-ES, for his assistance in defining the energy conservation options, and developing the energy planning module. Michael McCulley, Karen Ruby, and Kevin Frankland of USA-CERL were involved in the early stages of this project. Major portions of the formulation and verification of the energy building recommendations were performed by the Tennessee Valley Authority (TVA) and Lawrence Berkeley Laboratory (LBL) under interagency agreements. The technical editor was Jane Andrew, USA-CERL Information Management Office.

COL Carl O. Magnell is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

IMPROVED PLANNING AND PROGRAMMING FOR ENERGY EFFICIENT NEW ARMY FACILITIES

1 INTRODUCTION

Background

The Military Construction, Army (MCA) process is the Army's primary funding and delivery system for providing new facilities in response to changing mission goals. Researchers at the U.S. Army Construction Engineering Research Laboratory (USA-CERL) studied the energy impacts of this process and reported the results in USA-CERL Technical Report (TR) E-188.[1] This report concluded that although the present MCA process does not hinder the delivery of energy efficient buildings, it does not insure energy-efficiency, nor does it encourage the planners and designers to produce such facilities. Improvements in the process are needed because the decisions made in each phase can have a significant impact on the ultimate energy use of a proposed building. When properly selected and employed, energy conserving strategies can result in significant energy savings for new Army facilities.

A building's energy use is the result of the interaction of many factors, including climate, building functional requirements, envelope characteristics, and the mechanical system design. The earlier in the MCA process that strategies for reducing energy use are investigated and incorporated into the proposed facility, the greater the potential for successful energy reduction. However, planning, programming and early design guidance, analysis tools, and evaluation procedures for energy considerations are limited. Thus, energy considerations are included ad hoc rather than as an integral part of the early phases of the MCA process. Consideration of energy impacts during long-range and master planning is minimal, involving primarily the evaluation of conventional energy sources and effects upon existing utility systems. Similarly, the consideration of energy during programming and early design is not required, even though decisions made at these phases can significantly affect a building's final energy performance. The present MCA building delivery process does not emphasize energy conservation until the late concept and final design phases.

Designers are not the only ones who can make decisions on energy conservation. Because operational costs are ultimately the responsibility of the installations' Directorates of Engineering and Housing (DEH) and Major Command (MACOM), their input during the programming and planning phases will also affect the final energy usage of the facility. Planners in these organizations can improve the designers' efficiency by identifying--in the early planning, programming, and design stages--which energy saving options warrant more detailed evaluation and which have limited potential. Further, any proposed energy requirements must be clear and concise. Designers already face tight schedules, which are compounded by the multitude of design criteria, both energy- and non-energy-related, that must be met on even the simplest of projects. Thus, the effort put into ranking energy strategies must be spent as productively as possible. Any proposed tools or procedures used to meet energy requirements should be easy to use or follow, while still providing valid results.

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[1] D. Leverenz, D. Herron, et al., *Energy Impact Analysis of the Military Construction-Army Building Delivery System*, Technical Report (TR) E-188/ADA135277 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], October 1983).

The need for energy-conscious guidance in the early stages of the MCA process could be satisfied by integrating recommendations into the existing DD Form 1391[2] and Project Development Brochures (PDB-1 and PDB-2).[3] These documents were chosen as the vehicles for energy-conscious facility planning because of the important role they play in the early stages of any project. The PDB-1 transmits all basic project requirements such as type of facility, size, and location. When a project is ready to be designed, more detailed information is included on the PDB-2. The DD Form 1391 is prepared with the aid of an interactive computer program, the 1391 Processor. In addition to project requirements and specifications from the PDBs, this form includes initial cost estimates.

In the process of researching possible guidance and tools for the planning and early design stages of facilities, USA-CERL has reviewed the work of other agencies in search of related energy studies.

Objectives

The objectives of this study are (1) to develop energy planning criteria, guidance, and procedures for Army MACOMs, installations, and districts to use in incorporating energy conservation for new facilities into the planning and programming phases of the MCA process, and (2) to pilot test and implement these new energy-conscious procedures. The energy-conscious planning criteria should be integrated into the present system in such a way that the Army staff workload will not increase and the energy usage of new facilities will decrease.

Approach

To achieve these objectives, the researchers:

1. Evaluated the existing construction-related guidance for Army planners and programmers.

2. Interviewed Army master planners and programmers to get their assessment of current energy analysis methods, criteria, and guidance and to determine their needs in these areas.

3. Established the potential energy savings from improved planning and programming for energy efficient facilities.

4. Defined the energy impacts of the functional requirements and characteristics of Army building categories.

5. Developed climate-based energy planning guidance that is based on building functions.

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[2]Department of Defense (DD) Form 1391, FY(76), *Military Construction Project Data* (HQDA, December 1976).

[3]Department of the Army (DA) Forms 5020-R and 5021-R, *Project Development Brochure, PDB-1* and *Project Development Brochure, PDB-2* (HQDA, February 1982).

6. Developed an expert system, using a commercially available shell, which incorporates this guidance. This guidance has been field tested in a Technology Transfer Test Bed (T^3B) program. Full results of this test will be published in a separate report, and the guidance will be refined based on the results.

7. Tested the energy recommendations for planners by doing detailed energy studies of two building types.

Mode of Technology Transfer

The recommendations of this report should be incorporated into future versions of the 1391 Processor and into guidance prepared for planners and programmers of new facilities. Recommendations have been submitted to HQUSACE for changing Army Regulation (AR) 415-15, *Military Construction, Army (MCA) Program Development*. This material should be included in the appropriate USACE PROponent SPonsored Engineer Corps Training (PROSPECT) courses for planners, project managers, and designers. The energy matrix discussed in Chapter 3 is presently being used in the course "Energy Conservation Design for New Buildings."

2 ANALYSIS OF THE PLANNING AND EARLY DESIGN PHASES IN THE MCA PROCESS

Before the planning stages of the MCA process could be analyzed for energy impacts, its functional phases and their interrelationships had to be identified. To do this, USA-CERL examined the planning documents of the MCA process to find areas that could be effectively enhanced with energy conscious guidance. These documents included AR 415-10, *Military Construction-General* (HQDA, 1 March 1984); AR 415-15, *Military Construction, Army (MCA) Program Development* (HQDA, 1 January 1984); and AR 415-20, *Project Development and Design Approval* (HQDA, 28 March 1974). USA-CERL TR E-188 was used as reference for energy considerations in the MCA process. Researchers also visited four installations (Fort Eustis, VA; Fort Story, VA; Fort Leonard Wood, MO; and Fort Carson, CO), and interviewed their master planners to obtain opinions and ideas concerning energy efficient design of new facilities. The familiarity that planners have with the existing conditions on an installation puts them in a good position to evaluate the energy conservation potential for a new facility, and exert influence on its design.

The MCA process consists of these activities:

- Planning and program development, which defines the need for the building and establishes the functional requirements
- Design
- Review activities, which periodically evaluate the planning and design
- Approval activities
- Construction
- Building acceptance.

These activities take place within four distinct time periods. These are generally recognized as the Guidance Year (GY), Design Year (DY), Budget Year (BY) and Program or Construction Year (PY). Figure 1 illustrates the MCA process. Alternatively, the activities can be grouped in three stages:

- Project Development; including Long-Range Planning, Master Planning, and Programming, which takes place in the Guidance Year
- Design; including Concept and Final Design, which takes place during the Design and Budget Years (this stage also includes reviews and approvals)
- Construction; which takes place in the Construction Year.

This report is primarily concerned with the project development phase, which roughly corresponds to the Guidance Year. The various activities included in Project Development are summarized below in the order they typically occur. Weaknesses and suggestions reported in interviews with installation representatives are also discussed.

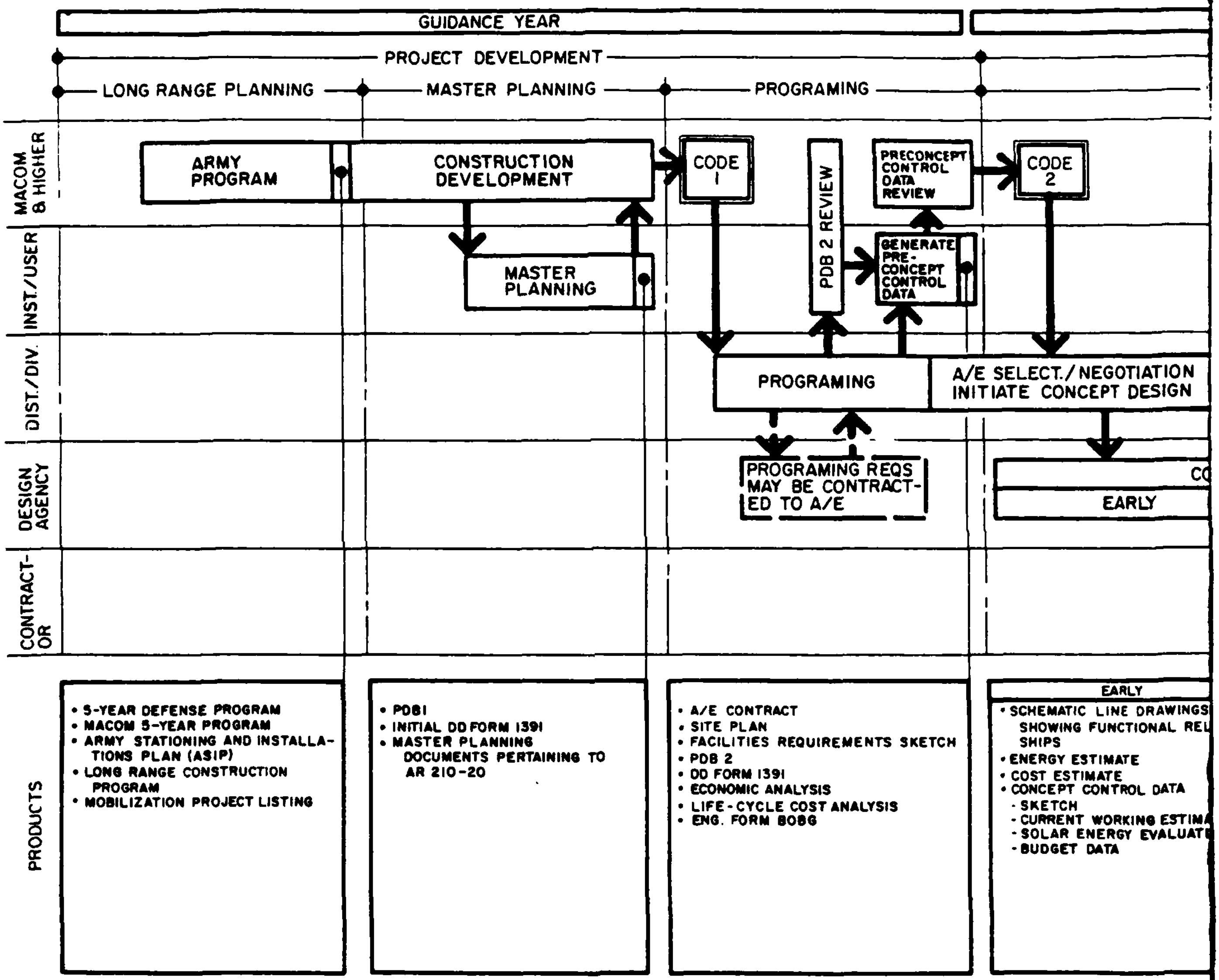

Figure 1. MCA process: steps, phases and products.

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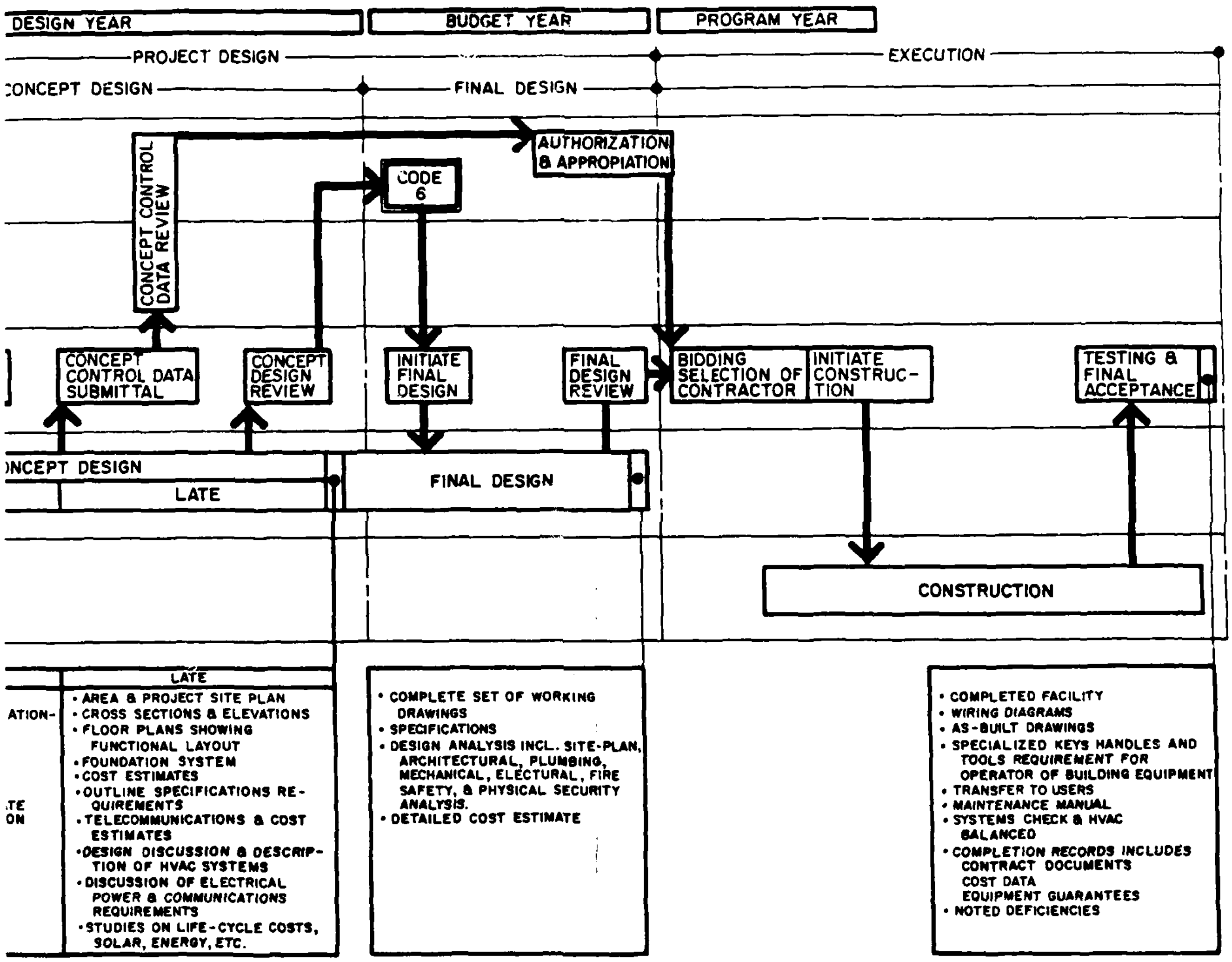
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• OUTLINE SPECIFICATIONS RE-QUIREMENTS
• TELECOMMUNICATIONS & COST ESTIMATES
• DESIGN DISCUSSION & DESCRIP-TION OF HVAC SYSTEMS
• DISCUSSION OF ELECTRICAL POWER & COMMUNICATIONS REQUIREMENTS
• STUDIES ON LIFE-CYCLE COSTS, SOLAR, ENERGY, ETC.
.TE
ON
• COMPLETE SET OF WORKING DRAWINGS
• SPECIFICATIONS
• DESIGN ANALYSIS INCL. SITE-PLAN, ARCHITECTURAL, PLUMBING, MECHANICAL, ELECTURAL, FIRE SAFETY, & PHYSICAL SECURITY ANALYSIS.
• DETAILED COST ESTIMATE
• COMPLETED FACILITY
• WIRING DIAGRAMS
• AS-BUILT DRAWINGS
• SPECIALIZED KEYS HANDLES AND TOOLS REQUIREMENT FOR OPERATOR OF BUILDING EQUIPMENT
• TRANSFER TO USERS
• MAINTENANCE MANUAL
• SYSTEMS CHECK & HVAC BALANCED
• COMPLETION RECORDS INCLUDES CONTRACT DOCUMENTS COST DATA EQUIPMENT GUARANTEES
• NOTED DEFICIENCIES

2 of 2

Current Long-Range Planning Process

Long-Range Planning is usually done at higher headquarters such as MACOMs, Department of the Army (DA), Department of Defense (DOD), National Security Council (NSC), or Congress. It is associated with planning for missions and mission changes. Typical long-range planning activities that affect the Army's facility requirements are stationing decisions, economizing measures, and force structure planning. During this phase, planners evaluate whether existing facilities can meet the mission requirements and determine if the facilities can be renovated or if new ones must be provided. As a result, long-range planning may lead to the modification of an installation's master plan.

Decisions made during long-range planning will ultimately affect energy use at all Army installations. The location of an energy-consuming facility can affect both fuel availability and overall utility cost.

Master Planning

Current Process

During the master planning process installations determine what real property changes are needed. Regional impacts, environmental concerns, utility requirements, existing services, and land use patterns for new facilities are all evaluated.

When a new facility is required, a Project Development Brochure (PDB-1) and an initial DD Form 1391 are produced. These documents contain the users' functional requirements, justification for the facility, and initial cost data. These are sent to the installation's MACOM for prioritization in the MACOM's Five-Year Program.

Many of the decisions a master planner makes at this early point in the MCA process will affect the total energy consumption of the facility and could help minimize the use of costly fuel sources. Because of existing physical constraints, many considerations may be limited to only the immediate vicinity of the new facility's site. Whenever possible, careful planning of new road networks, utility systems, building orientation, and general site configuration can improve the feasibility of using central energy plants, existing energy distribution systems, and passive solar design techniques. Master planners should also consider factors such as terrain, vegetation, and surrounding structures, which influence the amount of solar radiation and wind and affect the use of passive energy.

Field Comments

Misunderstanding and Misinterpretation. Because master planning is a phased process, much of the necessary data often is not available until the next phase. Frequently, the master plan appears to indicate more detail than intended concerning such things as building shape, orientation, and location. Master plans are sometimes misused because of too-literal interpretations, e.g., a rough site sketch using a standard building footprint is taken as a final design solution.

Limited Impact on Energy Conservation. Increasing consideration of energy impacts at the master planning stage will not necessarily result in more energy conservation. The actual impact of master planning on potential energy savings is reduced for two reasons. First, revising a master plan when a proposed usage conflicts with an existing master plan can change the energy criteria. Second, the existence of a strongly established road and utility network at bases limits the range of options (such as building envelope or orientation configurations) base master planners can recommend.

PDB Misconceptions. The PDB is used to develop and record information necessary to program, budget, and initiate the design of proposed projects. It does not describe design solutions. The Facilities Requirements Sketch required in the PDB suggests a significant amount of detail about building shape, orientation, and location, all of which have energy implications. The sketch does not dictate a building shape. It is only for illustration, and it may have come from a standard book of building footprints. Some designers may not know this, and they will base their designs on a strict interpretation of this sketch.

Inadequate Education. Many army and private sector master planners may be inadequately trained in planning for energy efficiency. PROSPECT courses are available for Army planners. Contracted master planners, from private A/E firms, would welcome access to simple, direct educational programs concerning energy guidance within master planning.

Facility Programming

Current Process

Facility programming is the phase that sets guidelines for the design of a specific project. After design Code 1 (see Figure 1) is received by the Corps and the installation from the DA Construction Requirements Review Committee (CRRC), detailed programming requirements for the facility can be developed. The installation begins facility and site-specific planning, and prepares detailed functional requirements and cost estimates for the DD Form 1391 and PDB-2. After this phase has been completed, the MACOM establishes functional requirements, budget requirements, and design priorities for the facility.

Many nondesign decisions are made at this stage, in areas such as site evaluation, climate conditions, and functional requirements. Even though these are not design decisions, they can affect the energy use of the completed building. Unfortunately, they are often made without complete information about their energy implications.

In the final formulation of the facility programming documents, the district project manager determines the emphasis on energy. The project manager relays information from the installation master planning staff to the designers doing the preliminary phase of design. The effectiveness of this communication link will influence the project results.

Field Comments

Interdepartmental Conflicts. When occasional conflicts occur in Army projects between criteria from the installations/MACOMs and Office of the Chief of Engineers (OCE), the district project manager normally follows only the OCE directives. This may cause useful and relevant input on energy to be overlooked.

Energy Budget Review. This review does not normally occur in the MCA process until the design is 35 percent complete. This is too late in the design process to make a significant change which reduces the effectiveness of the review. Also, when budget reviewers must economize, the costs for building in energy efficiency seem to be the first ones cut from the budget.

Lack of Consolidated Design Data. This hinders the task of meeting all relevant criteria. Users would like all the Army's building energy regulations and design data to be consolidated into one manual. There is also an important need for a follow-up system to track down and identify common problems. The absence of such a system discourages the establishment of a learning process from one project to the next. Although solutions may have been produced for problems found in the field, the shortage of design problem feedback allows common errors to recur.

Standard Building Designs. Standard building designs may be built without sufficient regard to location, climate, or applicability. The intent of the standard building design program, however, is to save on building layout and other design costs, not to provide designs that are taken "as is" and finalized without regard to actual location conditions. Lack of proper site adaptation will result in buildings that are not energy efficient and unsuited to the user's functional requirements.

Design Tools and Design Review. There is support from the Training and Doctrine Command (TRADOC), HQUSACE, and installation base master planners for planning guidance based on climate and building functional type. There is also interest in energy performance standards and in greater use of life cycle costing.

The current design review process may also need some improvements. Users, such as the installation and MACOM, need to be brought into decisions made during the design process so they can assure themselves that their needs are being met. In general, communication between the design agent (USACE) and the user needs careful attention.

Budgeting. Facility engineering staff have a hard time coming up with reasonable building energy costs for the 1391 that include operational and life cycle cost considerations. Building energy budgets often are based only on lowest initial cost, and not life cycle cost.

3 SUGGESTED ADAPTATIONS TO EXISTING GUIDANCE AND METHODS

To strengthen the awareness of energy conservation during the early planning stages of a facility, energy considerations have to be integrated into the PDB and the DD Form 1391 documents. These documents were examined to determine if they contained areas that could be improved in terms of energy conservation. The following sections briefly describe the PDBs and 1391 and give recommendations for increasing recognition of energy conservation during their preparation.

Recommendations for changes in AR 415-15, based on the issues discussed here, have been submitted to HQUSACE, Military Construction Management Branch on DA Form 2028, *Recommended Changes to Publications and Blank Forms.*

Project Development Brochure

The purpose of the PDB is to develop and record (in two phases) the data necessary to program, budget, and initiate design of proposed construction projects.

AR 415-20 refers the reader to Technical Manual (TM) 5-800-3, *Project Development Brochure* (HQDA, 15 July 1982) for instructions on preparing PDBs. The TM contains the standardized forms for the PDB. AR 415-20 does not apply to AR 210-50, *Family Housing* (HQDA, 1 February 1982) or to AR 415-35, *Minor Construction* (HQDA, 15 September 1983). However, because the PDB provides a convenient and useful method for establishing the requirements and technical data for a project, it is recommended for all projects.

The main purpose of the PDB is to express any special requirements, known only to the user/preparer, which are necessary to make the project a functional facility, and to provide data and recommendations to assist designers in developing effective and satisfactory solutions. The PDB should not describe design solutions, select materials of construction, or make other decisions which are properly left to the professional judgment of the designer or construction agency, unless there is adequate reason for doing so. The PDB should not repeat information that is normally carried in design guidance and manuals such as the Architectural/Engineering Instructions (AEI) or, TM 5-800 series, and in design guides for specific facilities).

The first descriptive element of the PDB is a narrative outline stating the general nature of the project and its intended function. The remaining elements give information which the design/construction agency must consider in its approach to the design of the project.

Phase 1

The information developed in the PDB-1 is general in nature and is designed to pull together the information required to prepare the initial DD Form 1391 and to provide preliminary information about a project to the MACOM. The PDB-1 helps establish a reasonably accurate scope for a project and identify items which will have a significant impact on project cost. The installation DEH has primary responsibility for the development of the PDB-1.

The PDB-1 has five main parts:

1. Cover Page: project name, using organization information (from AR 415-28 *Department of the Army Facility Classes and Construction Categories* [HQDA, 1 November 1981]), and project number

2. Functional Requirements Summary: objective of the facility and occupant organizations, types of spaces (including major requirements and size), and any anticipated changes

3. Facilities Requirements Sketch: a sketch of all primary facilities and all supporting facilities

4. Documentation Checklist: preliminary checklist of approvals, coordinations, studies, analyses, and similar items which must be acted upon in the early stages of project planning

5. Technical Data Checklist: the technical and site development items which are significant for sizing and costing a project.

Items 4 and 5 include several project categories such as Special Considerations (risk, construction requirements); Site Development; Architectural and Structural; Mechanical, Electrical, and Utility Systems; Environmental Considerations; and Fire Protection. Checklist functions in these items are classified as Required, Not Required, To Be Determined, Comment Attached, or Document Attached.

Suggested Strategies for Phase 1

1. During the preparation of the Functional Requirements Summary and Facilities Requirements Sketch, it is suggested that energy conservation techniques appropriate to that facility type and the particular spaces it is made up of should be considered. The reasoning for this is to initiate the awareness of energy conservation at this early stage of project development. Basic energy considerations which could be incorporated into the formulation of the Facilities Requirements Sketch include microclimate considerations such as wind speed and direction; building orientation factors such as solar availability, functional groupings, and axial considerations; and building volumetric alternatives. In keeping with the general nature of the Summary and Sketch, these considerations should be kept as simple and basic as possible. Also, detailed study of these is the designer's responsibility.

2. During the preparation of the Documentation and Technical Data Checklists, attention should be given to the Mechanical, Electrical and Utility Systems category to be sure the necessary analyses are done to provide the most energy efficient systems. An important analysis that can have a significant effect on the completed facility is the life cycle cost analysis[4] of various fuel types and conservation strategies. This study should definitely be done.

3. Items in the Technical Data Checklist which may affect energy consumption and should be addressed at this point are site development and landscaping and possible use of passive techniques. The life cycle cost of these techniques should be considered.

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[4]AR 11-28, *Economic Analysis and Program Evaluation for Resource Management* (HQDA, 2 December 1975); Technical Manual (TM) 5-802-1, *Economic Studies for Military Construction Design—Applications* (HQDA, 31 December 1986).

Phase 2

The information developed in the PDB-2 is detailed, consisting of total user requirements and complete site and utility support information. Principal responsibilities for the PDB-2 preparation lie with the design agent, the Corps of Engineers District Office. The user's contribution to the PDB-2 consists of the detailed functional requirements for the facility.

The PDB-2 is organized like the PDB-1 and contains updated, or more detailed, information about the facility. Like the PDB-1, the PDB-2 has five main parts:

1. Cover Page: project name and number

2. Detailed Functional Requirements: summary and detailed data information that is structured for the designer's use in developing a satisfactory solution

3. Facilities Requirements Sketch: sketch that is essentially identical to the one for the PDB-1, though it should be updated for the PDB-2

4. Documentation Checklist: an updated PDB-1 Documentation Checklist

5. Design Data Checklist: detailed checklist of supporting information and cross references to items in the PDB-1 Technical Data Checklist.

Items 4 and 5 are classified like the similar items in the PDB-1.

Suggested Strategies for Phase 2

1. Using the detailed users' functional requirements, areas that should be analyzed at this time for their impact on energy use are:

- The interrelationships of the various spaces can be determined with the use of an energy matrix (based on standard adjacency matrices: see **Additional Tools** below for discussion and example).

- The orientation- and location-related functional requirements of the space can be studied with respect to the space environmental requirements.

- Site location studies should be completed and related to placement of functional spaces.

2. The same careful attention should be given to the Mechanical, Electrical and Utility Systems category when the Documentation Checklist is updated as when it was first prepared.

3. In preparing the Design Data Checklist, energy conserving strategies should be incorporated into the various disciplines, e.g., site, architectural, mechanical, etc. Energy conservation techniques could be briefly reviewed and rated for immediate rejection or further study.

DD Form 1391 Submittal Package

The DD 1391 is a programming document which furnishes descriptive data, cost estimates, and justification data for a project. The 1391, like the PDB, is produced in two phases: (1.) initial or "front page," which is seen at all levels of review, and (2.) full, which contains more detailed and supporting information. The 1391 data is seen/ reviewed by all organizations up the chain of command from the user/preparer--the MACOM, Headquarters, DA (HQDA), and Office of the Secretary of Defense (OSD)/ Office of Management and Budget (OMB)--and is eventually submitted to Congress for review and approval. There are numerous occasions in this path when a project may be rejected due to incomplete or inaccurate data on the 1391. Requirements for preparation of the 1391 data are provided in AR 415-15.

Initial DD Form 1391

The initial ("front page") DD Form 1391 contains 11 blocks of information:

Blocks 1 through 7. These contain identifying project information such as date, location, facility type, category code, size, etc. The gross floor area listed here must be carried throughout the design because the scope of any project acted on by OSD, OMB, and Congress cannot be increased. As defined in Glossary 4 of AR 415-15, gross floor area is

> The total usable area of all floors, including mezzanines, basements and penthouses as determined by the effective outside dimensions of the building. One half area shall be included for uncovered loading platforms, covered ground level or depressed loading facilities and covered but not enclosed passageways, porches, and balconies and stairs. Exterior uncovered stairs, uncovered stoops, paved terraces and all enclosed space having an average ceiling height less than 7 ft shall be excluded.

Unless noted, the gross area allowance does not include required mechanical equipment space.

Blocks 8 and 9. These contain cost estimates. Block 8 is the total estimate, and Block 9 itemizes costs in some detail. Contingency and supervision and administration (S&A) costs are also shown here.

Block 10. This contains a description of proposed construction.

Block 11. This contains additional mission requirements and discussion.

Suggested Strategies for Initial 1391

Blocks 1 through 7. The type and size of the facility and its location are the main inputs for choosing energy conserving techniques. A computer-based system could be used at this point, possibly in conjunction with the 1391 Processor, to suggest appropriate strategies before cost has been established.

Blocks 8 and 9. The cost of energy saving strategies should be available to the planner. Mechanical system costs are currently integrated into the square foot primary facility costs. This cost could be broken out and listed separately as a supporting facility, as the electrical systems are now. Likewise, costs for other energy conserving strategies, such as special passive solar considerations, should be listed in these blocks. Operation and maintenance costs of alternative mechanical systems could also be shown here. "Site improvements" fall under the category of Supporting Facilities. Landscaping as a means to conserve energy can be considered under this heading.

Block 10. Any unusual energy saving techniques can be brought up here, such as underground building, berming, active solar technologies, or trombe walls.

Full DD Form 1391

The full DD Form 1391, created after initial (Code 1) authorization, contains four groups of information:

Initial 1391. The data described previously is included in its entirety.

Eighteen Justification Paragraphs. Of these, Paragraphs 1, General; 5, Criteria for Proposed Construction; 11, Economic Justification; 12, Utility and Telecommunication Support; 14, Project Development Brochure; and 15, Energy Requirements have direct energy implications. These paragraphs deal with general information, fuel type information, site sketches, utility support, and a summary of the Energy Requirements Appraisal that appears in Special Requirements Paragraph 3 (see below).

Special Requirements Paragraphs (SRPs). SRP3, the Energy Requirements Appraisal, should contain statements on how the project will comply with energy conservation demands and on alternatives that will reduce energy demands. The subparagraphs of SRP3 include: Estimated Energy Consumption for Heating System, Air-Conditioning System, Water Supply; Energy Sources for Heating, Electrical Power, Air-Conditioning; Energy Conservation; Energy Alternatives; Energy Effects; and Basis of Appraisal. The other SRPs have limited energy implications.

Supplemental Data Blocks A through F. Block A contains the estimated annual operational costs for the proposed facility, including energy costs. Blocks C and D present 25-year life cycle cost figures for the proposed facility, including energy costs. The other blocks have limited energy implications.

Suggested Strategies for Full 1391

Justification Paragraphs. Results of required studies of alternative fuels (or a justification of why a study was not necessary) could be placed in Paragraph 1. The building orientation aspect ratio (ratio of surface area to volume) and solar access should be considered when the site sketch is prepared.

A comparison of the energy consumption of the old facility and the proposed facility might be inserted in Paragraphs 2 through 4, as appropriate.

Exceptions to established criteria must be discussed in Paragraph 5, including any anticipated differences from DOD energy budgets. New criteria based on climate and/or building function must be proposed at this time. If an alternate energy type analysis was warranted, it could be presented in Paragraph 12. A summary of a life cycle cost analysis of a building's energy consumption could be included as part of Paragraph 15.

Special Requirements Paragraphs. The required energy budget could be compared to the estimated consumption in SRP-3, the Energy Requirements Appraisal, to roughly estimate what changes should take place. In addition, a life cycle cost analysis should be made to find out the financial impact of reducing energy consumption over a long period of time. A few separate analyses could be done using various energy saving techniques, including passive solar methods. However, it should be noted that energy budgets are design measures for judging design alternatives and are not meant to be used to estimate actual consumptions.

Accompanying the SRPs are site plans that represent relationships between the project, supporting facilities, and related facilities and show the suitability of the site for the project. Two items that should be considered when preparing the site plans are the orientation of windows and entrances and the aspect ratio.

Supplemental Data Blocks. The estimated annual cost to operate the facility should be presented for several different options, each employing an energy saving technique that has already been chosen for its optimum performance. The number of persons needed to operate the facility and the life cycle cost should be given for each option also.

Facility - Space Breakdown

Recognition of energy conservation during the early design stages can also be increased. This can be done by studying the major space types within a building and the energy aspects associated with those space types.

Ongoing research, such as that conducted by the TVA and the Department of Energy (DOE), illustrates energy usage of buildings based on space types contained in those buildings.[5] However, guidance presented to the planners and to the designer (through the PDB and 1391 documents) represents only the abstract category codes of the facility (from AR 415-28). Some generic space types are inherent in certain categories, but additional work will be necessary by the designer to determine an exact breakdown.

Merely breaking down the proposed facility into space types is not sufficient to completely categorize the building's energy use. Whole buildings must be considered since differing space types may cause synergistic effects in the building's energy consumption.

Energy Matrix

A tool used in early design, the adjacency matrix concept, can be adapted for considering energy impacts on the facility. The energy matrix presented here grew from a seminar held at USA-CERL in February 1984.[6] A group of interested architects and engineers discussed various approaches that could be used as tools in early considerations of energy impacts. The group wanted simple, accurate methods of describing energy aspects of buildings based on information known at a particular design stage. The energy

[5] *Development of Whole-Building Energy Design Targets for Commercial Buildings: Phase I—Planning* (Department of Energy, August 1987).

[6] Dwight Beranek, Minutes of USA-CERL-sponsored Early Design Seminar, February 1984.

matrix combines the typical information of adjacency matrices with the energy requirements identified in research such as that of TVA and DOE. When a new building is in the concept design stage, this matrix can be used to evaluate the energy-related aspects of the facility. An example matrix is shown in Table 1. The column headings used in Table 1 are explained in Table 2. The requirements were validated in studies done by Lawrence Berkeley Laboratory (LBL) in connection wih this research.

This energy matrix concept is being taught in the USACE PROSPECT course "Energy Conservation Design for New Buildings."

Table 1

Energy Matrix

Room/ Space Type	Heat Producing Equipment	Temp Req. (°F)	Occupancy Schedule (hr/day)	Light Level (ft.c)	People Load	Vent Load	Area (weighting factor)
Private Offices	MIN	68-78 H-C	8-5 5-day	50	LOW	MED	%
Admin.	MED	68-78	8-5 H-C	50 5-day	MED	MED	%
Class-rooms	MIN	68-78 H-C	8-10 6-day	50	HIGH	HIGH	%
AV/ADP	MAX	75	8-5	50 5-day	LOW	LOW	%
Confer-ence	MIN	68-78 H-C	Intermittent 5-day	30	HIGH	HIGH	%
Storage	MIN	50-90	N/A H only	5	NIL	NIL	%
Rest-rooms	MIN	68-90 H only	8-10 6-day	20	LOW	HIGH	%
MECH	MAX	50-90 H only	N/A	15	NIL	NIL -HIGH	%

Table 2

Energy Matrix Headings

Room/Space Type	The space designation that would typify a room or group of rooms. Examples are: private offices, open offices, classrooms, computer rooms, conference facilities, restrooms, laboratories, living quarters, kitchens, etc.
Heat Producing Equipment	An indication of the amount of heat producing equipment that would be located in areas of that space type. Minimum, Medium, and Maximum could be used during early planning stages with actual amounts filled in for a building after more detail is known.
Temperature	The temperature controls that will be used to moderate the space. An indication is given as to whether the space will be heated (H), cooled (C), or some combination thereof.
Occupancy Schedule	Scheduled occupancy times in hours/day and week.
Lighting Level	An approximate lighting level given, either in foot candles or other appropriate units or in ranges such as Minimum, Medium, or Maximum.
People Load	An indication of the number of people in the space type. High, Medium, Low, or None could be used in beginning planning stages, whereas later planning and design stages could designate actual amounts.
Area (weighting factor)	An indication, by percent or proposed square footage, of amount of the space type in the entire facility. This number can be used as a weighting factor in determining the effectiveness of a proposed energy conservation measure. For example, if an energy conservation measure could be very effective in a generic space type, but that space type were only a minimal area of the building, then the energy conservation measure could be seen, in context, as not being a significant impact to the overall building energy consumption.

4 DEVELOPMENT OF NEW GUIDANCE AND METHODS

Energy Conservation Options

The TVA developed a list of energy conservation options that could be applied prior to the very early stages of Army facility design. USA-CERL developed descriptions for these options, which are listed in Appendix A. PDB-1 facility specifications are broad; thus these options are quite general. From this pool of possible solutions, several alternatives can be chosen that are suitable for the specific facility and location.

Option Selection Matrices

Given this pool of options, some criteria are needed to guide the planner in selecting appropriate ones. The TVA adapted a method from their previous research[7] for use with Army buildings. This method uses a set of three matrices that allow planners to use space and weather criteria to select options for a facility in a given location. The complete matrices are given in Appendix B. They use 12 space types, 13 space-dependent criteria, and 15 weather criteria; these are listed in Appendix B, Table B1.

The planner first assembles the space and weather data. Matrix 1 gives characteristic values for the space-dependent criteria, by space type. These are dimensionless ranking values, which are based on a scale of 1 to 10. (The one exception is air rate, which denotes maximum air flow rates in fpm.) For example, the space type "classroom" has a "daytime use" value of 8. Weather data is not given in this report; it is available from other sources.*

To find feasible options, the planner compares the space characteristics and weather data for the facility in question with threshold values for each option. For each energy conservation option from Appendix A, Matrix 2 gives the thresholds for weather criteria, and Matrix 3 gives the thresholds for space criteria. (Matrices 2 and 3 are shown together for convenience.) A column showing >= or <= indicates whether the value for that criterion is a lower or upper limit, respectively. For example, one threshold for the option "direct gain glazing" is "daytime use" >= 7.

An option is feasible for a given space type only if it meets the threshold for every criterion. A variety of feasible options will be found, corresponding to the various space types in the facility. For example, direct gain glazing might at first seem like a feasible option for classrooms. Its daytime use is 8, above 7 as required; nighttime use is 2, below 3 as required. However, its occupancy level is 10, where Matrix 3 requires an occupancy level <= 4. That means direct gain glazing should not be used in classrooms.

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[7] *Energy Design Guidelines for Schools* (Tennessee Valley Authority [TVA], March 1985).

*USA-CERL generated the needed weather data from actual hourly weather data using the Weather Information File Encoder (WIFE) program of the Building Loads Analysis and System Thermodynamics (BLAST) system. Another source is the triservices manual, *Engineering Weather Data* (Air Force Manual [AFM] 88-29, TM 5-785, or Naval Facilities Engineering Command [NAVFAC] Publication NAVFAC P-89).

Generalized Energy Approach Sentence

Because of the large number of options, the TVA matrices are awkward to use. Therefore, two other matrices were developed that limit and prioritize the options. From these, the planner can generate a sentence (following a standard format) that indicates the energy conservation approaches which should be investigated further. This sentence could be used on the initial DD Form 1391.

The first step in developing these matrices was grouping the energy conservation options of Appendix A into 14 general categories. These categories were further grouped based on whether they contained primarily heating, cooling, ventilating, lighting or whole building options (see Appendix C for this hierarchy). Next, a matrix was created (based on professional judgment) showing the primary and secondary loads on a space by space type and Army climatic region. The loads considered were heating, cooling, ventilating, and lighting. Figure D1, Appendix D shows the seven Army climatic regions, and Table D1 shows the resulting matrix. Finally, a more detailed version of Table D1 was developed, shown in Table D2. It gives the number (1 to 14 from Appendix C) of the two general energy conservation categories which are most applicable for the given load (primary or secondary) in the specified space type and Army climatic region. Table D1 is needed to identify the type of load.

From Tables D1 and D2, enough information is now available to program a generalized energy conservation approach sentence. This is a suggested form for the sentence:

In a ____________ in region ________________, the principal energy
(space type) (Climatic region)
loads will be ________________ and ________________. To increase
(primary load) (secondary load)
the energy effectiveness of this facility, energy saving efforts
should be directed toward ________ ________________________
(option categories for primary load)
and ________________ ________________________.
(option categories for secondary load)

Example:

In an office in region 2, the principal energy loads will be heating and lighting. To increase the energy effectiveness of this facility, energy saving efforts should be directed toward Building Shell Strategies for Heating [2], HVAC Heating System Strategies [5], Building Shell Strategies for Lighting [11], and Lighting Equipment Strategies [12]. [Numbers are for illustration only; compare with Table D2.]

The process of using the data in the option selection matrices to produce generalized sentences could easily be automated. A help function further defining the generalized conservation categories could be included.

Budget Figures for Energy Conservation

New project designs are required to incorporate energy conservation features unless a life cycle cost analysis suggests that there are more effective alternatives.[8] That is, the amount spent on including energy conservation features must not exceed the expected life cycle (energy and/or other operating costs) savings from those features. Thus, planners must know the potential savings in $/sq ft that could be realized from each proposed option. This estimated savings could be included on DD 1391 in Blocks 8 and 9.

In this research, the potential energy savings was calculated for each USA-CERL/TVA space type at each Army installation. Three intermediate values were needed to arrive at this savings figure: a "before" energy consumption figure in kBtu/sq ft/yr, an "after" energy consumption figure, and the installation's energy cost in $/Btu. For the energy costs, figures from the National Bureau of Standards were used.[9] For the energy consumption values, USA-CERL chose to use the design energy target (energy budget) figures established by the Army and Air Force.[10] These artificial units of measure, which are used in setting design criteria, are the only well-establish means of judging the energy efficiency of buildings. The Army ETL was used for the "before" figures, since it reflected the energy design goals for FY85 buildings. The "after" figures came from the Air Force ETL, which sets the goals for FY95 and reflects the reduction that could realistically be achieved. (A 10 percent reduction from FY85 figures is mandated for new buildings.)[11] It is assumed that new buildings will be designed so that their energy consumption meets these goals. (The Army had not completed development of new guidance for FY95 at the time this work was done. The current Army energy guidance for FY95 is described in Architectural and Engineering Instructions-Design Criteria, Chapter II, "Energy Conservation Criteria" (OCE, 13 Mar 87.)

Some adjustment was necessary since the energy budget numbers in the Army and Air Force ETLs are given by facility category code instead of by the space types used in the matrices. Table 3 shows the correspondence between the USA-CERL/TVA space types and the Army/Air Force category codes.

To calculate the actual savings, the difference (in kBtu/sq ft/yr) was found between the Army (FY85) and Air Force (FY95) energy consumption figures. Then this difference was multiplied by the installation energy cost in $/kBtu, then by a 20-yr life cycle. The results of these calculations, the savings in $/sq ft, are given in Appendix E. The accuracy of these figures should be tested. Once their reliability has been proven, they can be considered for inclusion in the initial DD 1391.

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[8] *Architectural and Engineering Instructions—Design Criteria*, Chapter 11, "Energy Conservation Criteria" (Office of the Chief of Engineers, 13 March 1987).

[9] *Energy Prices and Discount Factors for Life-Cycle Cost Analysis*, NBSIR 85-3273 (National Bureau of Standards, November 1985).

[10] Army Engineering Technical Letter (ETL) 1110-3-309, *Interim Energy Budgets for New Facilities* (USACE, 30 August 1979); Air Force ETL 86-1, *Energy Budget Figures (EBFs) for Facilities in the Military Construction Program* (U.S. Air Force, 3 February 1986).

[11] Department of the Army Energy Resources Management Plan FY86-FY95 (Office of the Deputy Chief of Staff for Logistics, 21 January 1987).

Table 3

Correlation of Space Types and Army/Air Force Category Codes

USA-CERL/TVA Space Type	**Army Category Code**
Classroom	School
Laboratory	Research and Development
Office	Office
Circulation	No matching space types
Lounge	Average of Community Facilities-Personnel, Community Facilities-Moral, Welfare, Recreational, and Clubs
Cafeteria	Dining Facilities
Library	Office
Warehouse	Storage
Garage	Storage
Computer Center	Research and Development
Flight Simulator	Research and Development
Barracks	Average of housing---Family and Bachelor
Medical Facilities	Hospital Buildings

USA-CERL/TVA Space Type	**Air Force Category Code**
Classroom	School (Ceiling: 10 ft)
Laboratory	Instrumentation and Testing Facilities
Office	Office (area > 8000 sf)
Circulation	No matching space types
Lounge	Clubs
Cafeteria	Dining Facilities
Library	Community Facilities
Warehouse	Average of Heated Storage and Storage
Garage	Average of Heated Storage and Storage
Computer Center	Instrumentation and Testing
Flight Simulator	School
Barracks	Housing
Medical Facilities	Hospital Building

5 PRELIMINARY AUTOMATED ENERGY PLANNING MODULE

Although TVA's selection matrices (described in Chapter 4; shown in Appendix B) work quite well in selecting energy conservation options, the task is quite time-consuming and tedious to do by hand. An automated module would minimize the effort needed to implement the matrices and would make the selection process more efficient. After proper field testing, the module could be considered for incorporation in the 1391 Processor.

Several meetings were held during the course of this project with the proponent and supporters of the 1391 Processor system. Though generally supportive of the USA-CERL effort, they noted that the 1391 Processor is mainly a text generating system. It does not interpret what the user has put into the blocks being created. Ideally, an energy planning module would generate recommendations by linking information on facility type, location, size, and cost. For such a module to operate within the 1391 system, as it currently stands, the planner would have to enter facility category codes, locations, sizes, etc. more than once.

Since the 1391 document is seen at many levels, including Congress, it must be very accurate. Therefore, rather than attempting to incorporate a premature and possibly inaccurate energy planning module into the existing 1391 Processor (which was under study for revision), the research focused on module development and verification.

Many different approaches would be feasible for developing an energy planning module, but expert system concepts are particularly attractive. An expert system could convert the information in the TVA matrices into a form that would be much easier to use. The expert system approach would also allow easy updates of the data base, and has the potential of having the system learn from new or more detailed information from the users. Expert systems can be developed using normal programming languages, specialized languages, or commercially available shells. In the interest of conserving resources, EXSYS*, an inexpensive shell for IBM-compatible personal computers was chosen. Using EXSYS and the data contained in the matrices, a prototype energy planning module has been developed.

The prototype system is relatively easy to use. It prompts the user in simple English for each input value. First it asks the user to select a location for the facility. From this the system determines what weather data to use in its analysis. For the prototype version, 13 locations were programmed into the system, but additional locations can be added. If the location the user wants is not available, he or she has the option of providing the weather data for the chosen location by selecting the option "weather data provided by user." The system then prompts the user for the building's space types. A list of 12 space types is provided, and the user simply selects the appropriate choice. The user can add additional space types the same way as locations. The selection of space types provides the system with the necessary space characteristics. The system then performs its analysis and lists the applicable energy conservation options for the facility. The order of the options has no significance.

Because the prototype system was developed as an example, it still has some rough edges. For example, the location must be repeated every time an additional space type is added. Also, if users want to add their own locations, they may have difficulty

*Published by EXSYS, Inc., Albuquerque, NM.

collecting all the various weather data required. Neither of these problems are insurmountable, and further development should resolve them.

Before this module can be incorporated into the 1391 Processor, it needs to be confirmed that the options selected by the module are appropriate to the facility being planned or designed. A Technology Transfer Test Bed (T^3B) field test has been conducted at seven District offices to evaluate and validate the module's energy conservation options. This is necessary because not all options are appropriate for all locations. The districts selected--Fort Worth, Louisville, Mobile, Omaha, Sacramento, Savannah, and Seattle--represent diverse geographical areas and climatic conditions.

Designers, engineers, and planners at the districts were asked to review the set of options, and apply them in theory to a variety of recently completed or in-progress projects within their jurisdiction. They were then asked to indicate which options had been or should have been properly studied in the designs for these projects. Details such as location, square footage, and major space types were requested for each project they evaluated. Comments were also solicited on the appropriateness of the weather data used to select options. Once the participants had selected options that they felt were applicable to the project(s) being reviewed, they were asked to rank them in order of importance. They were also asked to identify options inappropriate for the facility or for the individual space types contained in the facility. Finally, additions or deletions to the list of options were requested. This field test was completed at the end of FY87. The test and its results are being fully documented in a separate T^3B technical report.

6 EVALUATION OF ENERGY CONSERVATION STRATEGIES IN TWO STANDARD-DESIGN BUILDINGS

Under an interagency agreement with USA-CERL, Lawrence Berkeley Laboratory (LBL) did several energy analyses to verify the preliminary guidelines outlined in this report. These analyses were done using the Building Loads Analysis and System Thermodynamics (BLAST) program. LBL examined two standard-design buildings: a Battalion Headquarters building and a typical "Y" Barracks. First, they established prototype building descriptions for use with the BLAST program. Using the BLAST input descriptions, they analyzed the applicability and sensitivity of various building parameters to the building types. BLAST was also used to examine the effects of including various energy conservation options in the building descriptions. The sensitivity of design to climate in various locations was also considered. Finally, they developed planning/early design guidelines for the Battalion Headquarters. Similar analyses will be needed for other major building types.

Selection of Statistically Representative Weather Sites

To be most accurate, BLAST analyses should use exact weather data. However, this becomes time consuming and inefficient when done on a large scale, as in the present project. To address this problem, LBL has performed a climate analysis which statistically associates each of the many Army and Air Force locations with one of a small number of weather sites. LBL had previously developed methods for identifying appropriate representative weather sites for energy analysis on a nationwide scale.[12] That analysis was performed using annual climate parameters such as heating degree days, cooling degree days, humidity coincident with heat, and sunshine. The importance of a specific climate was weighed based on the general (civilian) population represented. Climatic similarity was also defined. The object of the analysis was to create climatic regions which can be reasonably represented by a single weather site, and which contain a significant portion of the target population.

These methods were based on the general population, whereas the military population is distributed somewhat differently. Therefore, LBL developed a new data base to incorporate military population distribution. (In the study, 158 Army and Air Force bases representing about 2 million persons were considered.) The results of this data base creation show that the major military population centers are Washington, DC, Texas, and the Carolinas. Secondary centers are the deep South, Kentucky, Oklahoma, Colorado, the Southwest, and Washington state. The traditionally population-dominant Midwest and Northeast have small military populations and therefore do not contribute much. A short list of five weather sites was assembled to examine variations due to broad climatic differences. A long list of 10 sites was also assembled to represent areas with less difference in climate. The short list is a subset of the long list.

[12]Anderson, B., W. Carroll, and Mr. Martin, *Aggregation of U.S. Population Centers Using Climatic Parameters Related to Building Energy Use*, Report LBL-15230 (Lawrence Berkeley Laboratory, 1985). Also available in *ASHRAE Transactions*, Vol 91, No. 2B (1985) pp 183-205, and in *Journal of Climate and Applied Meterology*, Vol 25, No. 5 (1986) pp 596-614.

The short list consists of:	Atlanta, GA San Antonio, TX Washington, DC Colorado Springs, CO El Paso, TX
The long list consists of:	Mobile, AL San Antonio, TX Washington, DC El Paso, TX Colorado Springs, CO Atlanta, GA Raleigh, NC Olympia, WA Sacramento, CA St. Louis, MO

Thus, all military bases of concern to USACE can be associated with one of these sites. This means that the climate of an individual base is closer to the climate of the associated weather site than to that of any other sites on the list. For example, the climate at Fort Sill can be represented by Atlanta, and Fort Riley, KS can be represented by Washington, DC. These representative weather sites could be used to reduce the amount of weather data needed in USA-CERL's prototype energy planning module.

"Y" Barracks Energy Characterization

To perform characteristic energy use of the barracks, BLAST runs were made using the barracks standard design at each location on the *long list*. For each BLAST run, electricity and fuel use were examined, with electricity use broken down into cooling, lighting, fans, and pumps. Fuel use was broken down into heating and domestic hot water (DHW) consumption. The next step was to alter parameters such as orientation or lighting level individually to check the sensitivity of energy use to variations of each parameter. Areas exhibiting great sensitivity were investigated further.

From the locations on the long list, Atlanta was chosen as the baseline, since it represents the greatest number of installations and because it represents a midrange climate. In the barracks simulations, it was found that electricity was used predominantly for lighting and cooling, while 67 percent of the fuel used was for heating and 33 percent for domestic hot water. Seventy-six percent of the total energy used was from fuel, while 24 percent was from electricity. In colder locations, heating fuel use was greater while cooling electricity was less, as could be expected. The opposite was true for warmer locations. In all locales, fuel use dominated, accounting for 70 to 90 percent of the total energy used. Therefore, the focus in barracks design should be on saving energy from reduced space heating and domestic hot water heating.

The variations in energy use changed rather predictably across the locations, so further studies focused on the two climate extremes of San Antonio, TX and Colorado Springs, CO. The results for the other locations should fall somewhere between the results for these two extreme climates.

Parametric studies were performed to note the effect of varying orientation, envelope finish, insulation levels, window treatment, electric lighting levels, and HVAC control strategies. This was done to determine how sensitive energy use would be to variations in each parameter. The areas that showed the most promise for large energy reductions can then be studied further.

Orientation and Envelope Finish. The studies revealed that the effect of orientation alone on the barracks is relatively small. The major effect of changing orientation is changing the facing direction of windows. Since the barracks have roughly equal window areas in all four directions, the effects were negligible. Changing the envelope finish also showed insignificant energy savings.

Insulation Levels. Examination of the insulation levels produced interesting results. Increases in wall and roof insulation produced only small energy savings. Increased floor insulation greatly increased the cooling load, apparently by cutting off natural cooling through the slab. Completely removing wall and roof insulation produced large increases in heating loads in both extreme locations. Apparently, an optimum level of insulation is reached rather quickly.

Window Treatment. Changing the windows from double to triple pane showed little effect. Increasing the window area showed very little effect in Colorado Springs, probably due to the fact that conductive losses were balanced by solar gains. Slight overheating occurred in San Antonio due to the solar gains from increased area. Reducing the window transmission in both locations increased fuel use, but decreased cooling loads since solar gains were reduced. Further study is needed to examine synergistic effects of window area, window character, and building orientation.

Lighting Levels. Increased lighting intensity dramatically increased electric use in both locations, in addition to increasing the cooling load in San Antonio. Lighting efficiency is critical in all locations, but particularly in climates where cooling load dominates.

HVAC Controls. In the area of heating, ventilating, and air conditioning (HVAC) control, expanding the range of the temperature deadband produced significant savings, but the cost of expanded setpoints to occupant comfort must be considered carefully. Cutting off the HVAC system to the bedrooms during the day produced only small savings.

Battalion Headquarters Energy Characterization

The study of the battalion headquarters proceeded in the same manner as for the "Y" barracks. The initial BLAST runs showed that electricity use was evenly split between cooling, lights, and fans. Fuel use was roughly 76 percent for heating and 24 percent for DHW. In Atlanta, the majority of total energy use is electricity, at 58 percent. Generally, warmer climates were electricity-dominated, whereas cooler climates were fuel-dominated.

For the battalion headquarters, parametric sensitivity was examined for building orientation, envelope finish, insulation levels, thermal mass, window treatments, electric lighting levels, and HVAC controls.

Orientation and Envelope Finish. Since there are large glass areas on two walls of the battalion headquarters building, orientation changes had a greater effect on energy use than for barracks, but the effect was still not dominant. Care must be taken in orienting a building to balance the positive and negative effects of having windows facing certain directions. Once again, envelope finish had only a minor effect on total energy use.

Insulation Levels. Doubling the wall and roof insulation produced only small effects for the battalion headquarters. Adding floor insulation yielded energy savings in Colorado Springs, but not in San Antonio. Total removal of insulation had a serious effect in Colorado Springs, and a smaller effect in San Antonio. Overall, the effects of changing insulation levels were smaller than for the barracks, since the battalion headquarters has a much higher internal load and is a thermally massive structure.

Thermal Mass, Window Treatment, and Lighting Levels. A small positive effect was gained by replacing the interior walls with masonry partitions, thereby increasing the thermal mass. Any change that makes this thermally massive structure lighter may or may not carry a penalty, so the effect should be examined. Only small effects were noted when window character was varied. Reduced lighting levels showed energy savings in both locations, but greater benefits were noted for San Antonio.

HVAC Controls. Once again, good energy savings were obtained for an expanded temperature deadband, but the battalion headquarters is not envelope-dominated, so the savings are not as great as for the barracks. Care still needs to be taken with regard to the comfort/cost trade-offs. Using night shutoff provided dramatic positive effects.

Preliminary Planning/Early Design Considerations for Battalion Headquarters

LBL did further work that took the battalion headquarters building through the preliminary guideline development stage. From the discussion above, the significant parameters are wall, roof, and floor insulation; building orientation combined with window location, size, and character; thermal mass; lighting levels and efficiency; and thermostat settings. Once again, Atlanta was taken as the baseline with additional runs for San Antonio and Colorado Springs. Other sites were examined until a clear pattern to the results was evident.

The guidelines discussed below are only preliminary. They do indicate, however, where savings can occur. For instance, depending on the type of facility and its location, a building may be designed with less insulation than it normally would if it can be shown that additional insulation would produce no further savings in energy. Further study is needed to ensure integrated solutions suited to the particular climate in question are found.

Wall and Roof Insulation. In examining wall and roof insulation, the levels were varied gradually to check the effect on energy use. Results show that benefits decreased gradually, with little additional savings after 4 in. Also, insulation is most effective when levels in walls and the roof are kept the same.

Floor Insulation. Floor insulation was studied for levels of 2, 4, and 6 in. in Atlanta, San Antonio, and Colorado Springs. Results were similar in Atlanta and San Antonio and can be assumed to be the same for all other warm climates. Differences between Atlanta and Colorado Springs results required additional BLAST runs for Washington, DC to refine the conclusions. Generally, as floor insulation is added, fuel use decreases, while electricity use increases. In San Antonio, the fuel load is small, so the negative effects in the form of higher cooling loads dominate. The same is true for Atlanta, to a smaller extent. In Colorado Springs, lower levels of insulation provide a net benefit even though there is a penalty in the cooling season. In Washington, floor insulation does provide a positive heating effect, but due to the high cost of electricity in that area, no floor insulation is still the least costly option. Thus, in most climates (particularly warm ones), floor insulation should not be used. In the coldest climates, 2 to 4 in. are beneficial.

Building Orientation and Window Treatment. Due to questions about BLAST's treatment of wings next to windows in the Battalion Headquarters model, no conclusions could be drawn as to the combined effects of orientation and window treatment.

Thermal Mass. BLAST runs were performed with lightweight partitions and lightweight walls to note the effects of thermal mass. All runs kept the concrete slab floor. A night setback was examined to check the storage effects of thermal mass. With a standard thermostat setting, fuel and electricity used dropped with increase in thermal mass. With night setback, changes in Atlanta were more pronounced in electricity consumption. In Colorado Springs, heating benefits were much greater, probably due to large heating loads and the sunny location. There is much to be gained by adding thermal mass, so caution should be used when considering any change that would reduce thermal mass.

Lighting Levels. Lighting levels from 1 W/sq ft to 3 W/sq ft were examined for each location. The dominant effect is a change in lighting electricity use. With reduced lighting, the cooling load decreases and the heating load increases, but these effects are secondary. It is important to remember that lighting quality is very important to occupant comfort and productivity, so reductions should be made with care. The benefits of using daylight should also be considered.

Thermostat Settings. The thermostat deadband was increased and decreased from the standard 71/76°F setting to examine the effects. The wider deadband settings required less energy. Ways to widen the deadband without upsetting occupants need to be examined. One method would be to make great efforts to maintain consistent space temperatures.

7 CONCLUSIONS AND RECOMMENDATIONS

This report has described the development and initial implementation of new and revised energy planning criteria and guidance. Planners at MACOMs, installations, and Corps of Engineers district offices can use these criteria and other suggestions given in this report as a means of placing more emphasis on energy conservation in the early stages of planning and programming, and thereby encourage the awareness of energy conservation in the later design stages.

Comments were solicited from the field regarding energy issues in the project development phase of the MCA process. They indicated that the master planning and facility programming stages have areas that could be improved, in general, by making more appropriate use of the data provided in project documents. For example, better energy cost estimates can be developed. By so doing, designers will be influenced to create designs that match user energy needs more closely. Chapter 3 discusses ways energy issues can be specifically addressed in the PDB-1, PDB-2, initial DD 1391, and final DD 1391.

A method was developed for narrowing the range of conservation options to be considered. It uses matrices which identify feasible options based on space data for the specific planned facility and weather data for the specific location. In its consolidated form, the method identifies four categories of options for a given space type, two each for the primary load and secondary load. Specific strategies can then be identified within these categories (Chapter 4 and Appendices A through E). This method has been implemented in a prototype expert system. The energy conservation options were evaluated in the field in a T^3B program. The results will be reported in full in another technical report (Chapter 5)

To help planners evaluate the savings that can be expected from energy conservation, the $/sq ft savings were calculated for each space type at each Army installation. These figures are based on the reduction in the energy budget numbers between FY85 and FY95, which set the energy consumption criteria that new buildings must meet. These savings figures give planners an idea how much can be spent on implementing the conservation strategies without jeopardizing the payback.

To develop preliminary planning and early design energy guidelines for typical Army buildings and verify the matrice data, energy analyses were done using BLAST to evaluate the overall effect of parameters such as orientation, lighting levels, window treatment, etc. Two standard-design buildings--a Battalion Headquarters and a "Y" barracks--were evaluated at several locations chosen for their representative climates. The headquarters building was evaluated further, at a more detailed stage of design. Based on these results, some very general guidelines are presented for the effective use of insulation, thermal mass, lighting levels, and thermostat settings.

To refine the work reported here and to put it to best use, the following actions are recommended.

- Incorporate the energy matrix (Chapter 3) as a tool for both planners and designers of new facilities. This tool can be presented as part of other training: it is already being used in the PROSPECT courses, "Energy Conservation Design in New Buildings."

- Incorporate energy considerations into the instructions for completing DD Form 1391 and the PDBs. Recommendations for changes to AR 415-15 have been submitted to proper authorities.

- Compare the information contained in the energy matrices with current practices.

- Implement an automated energy planning tool either through the expert system developed in this project or through similar additions to the 1391 Processor.

- Accurately determine how much the Army would save by using energy conservation options in its new facilities.

- Continue the research on the energy characteristics of major Army building types, and develop planning and early design guidelines specific to these facilities. This effort could be incorporated into the standard design documents for these facilities or into general design instructions such as the AEI.

- Focus future energy planning research work directly on the installation master planners.

APPENDIX A:

ENERGY CONSCIOUS DESIGN STRATEGIES*

1. **Air Barrier Curtains**--Air barrier curtains are strong, artificially created currents of air that provide protection from rushes of outdoor air when entries are frequently open.

2. **Air Destratification**--Air destratification prevents air layers from forming large indoor spaces and thus provides greater circulation of heated air. The most common form of air destratification is ceiling mounted fans that recirculate the heat downward in buildings where ceiling heights exceed 12 ft. Depending on fan diameter and ceiling height, each fan can handle between 1000 and 3000 sq ft of floor area.

3. **Airlock Entries**--A double set of exterior doors create airlock entries. This strategy reduces loss of conditioned interior air and reduces infiltration when exterior doors are used.

4. **Air-to-Air Heat Exchangers**--These exchangers transfer heat directly from one airstream to another through direct contact on either side of a metal heat transfer surface (e.g., an institutional kitchen where heat from steam kettles is collected by a hood and then is processed through the air-to-air exchanger to heat the incoming makeup air).

5. **Building Shape and Orientation**--Building shape, when elongated on the east-west axis, minimizes heating loads in the winter and cooling loads in summer. For adequate daylighting of interior spaces, the space depth (i.e., the length between the window wall and the opposite wall) should be less than 2.5 times the window height.

6. **Daylighting**--Daylighting is the use of sunlight instead of artificial sources to illuminate interior spaces. Configuration of the spaces within a building should allow the majority to be within an optimum depth of 25 ft from the windows. In conjunction with other strategies (e.g., skylights, lightscoops, lightwells, and atriums), windows can illuminate greater space depths.

7. **Daylight Responsive Lighting Controls**--Daylight responsive lighting controls should be used in conjunction with a daylighting strategy. These controls sense when natural light is supplying enough illumination and shut off unnecessary artificial sources.

8. **Decreased Supply and Make-Up Air**--Decreasing the amount of supply and make-up air reduces energy loss by lowering total circulating energy in an air system. It reduces fan horsepower energy as well. Care should be taken not to decrease the air comfort level.

9. **Direct Evaporative Cooling**--A direct evaporative cooling system cools outside air through water spray, and supplies the cooled air to interior spaces. As outside air enters the water system, it is cooled to the required humidity level while keeping the same enthalpy level, and then is adjusted for the required temperature level. Since this system is simpler than indirect evaporative cooling systems or refrigeration air-conditioning systems, its first and utility costs are comparatively lower.

*Listed alphabetically.

10. Direct Gain Glazing (Direct Solar Gain)--Direct gain glazing systems use sunlight penetrating through solar glass areas to heat the actual living space. To collect solar energy and store it for night use, large south-facing glazing and sufficient thermal mass are needed. The floor and/or walls must be constructed of materials capable of storing heat. The most common materials used for heat storage are masonry and water. Direct gain systems work well in sunny climates, as well as in cloudy climates where active solar systems cannot perform as effectively. South glazing should be 10 to 40 percent of the floor area, and typically 1/2 to 2/3 of the total surface area in a space is constructed of thick masonry.

11. Double Glazing--Window assemblies which use two panes of glass in each frame are double glazed. The air space between the glass increases the insulating value of the window assembly.

12. Dry-Bulb Temperature Economy Cooling--In an economizer cooling system, the temperature of the outdoor air is monitored to determine whether or not it is cool enough to provide free cooling to the system. If the outdoor air is cool enough, the dampers in the system bring in cool outside air, reducing or eliminating the need for mechanical cooling.

13. Duty Cycling--Duty cycling is a control strategy under which mechanical equipment is cycled on a preprogrammed basis during periods of heavy electrical demand within a building. The equipment cycling serves to reduce the peak demand of the building.

14. Earth Berming--Earth berming uses the natural insulating value of the soil. Earth is sloped up to cover all or part of the exterior walls of a building. Berming earth against the north wall in cold regions reduces heat loss and protects the building from the prevailing winter winds. Care must be taken in humid climates to prevent excessive humidity and mildew from occurring within the building, particularly in summer months.

15. Efficient Artificial Lights Compatible with Daylight--Efficient artificial light sources can be used in conjunction with daylighting principles to reduce lighting loads.

16. Efficient Fixtures and Lamps--The most efficient fixtures and lamps should be used in order to reduce lighting loads. Illumination level, fixture placement, and coloration should not be sacrificed.

17. Electronic Filter--Electronic filters remove odors and pollutants in supply air. They allow greater reuse of return air and minimize the amount of outdoor air. In a system that uses large quantities of outdoor air, first and operating costs can be saved by reusing return air, which reduces the use of outdoor air.

18. Energy Monitoring and Control System (EMCS)--EMCS is an automated system for controlling the energy consumption functions of a building and minimizing the energy usage through optimization. It includes thermostats, time switches, programmable controllers, microprocessor systems, computers, and sensing devices that are linked with control and power components to manage energy use. This system optimizes load control to achieve the lowest possible cost of operation consistent with proper and effective functioning. It can supervise the operation of lighting systems, HVAC, and other equipment and provide this automatic control relative to demand and energy consumption.

19. Exterior Venting of Heat-Producing Equipment--Heat from interior equipment is one of the major internal heat gain factors. Exhausting the heat from the equipment to the outside may greatly reduce internal heat gain and cooling loads, particularly in hot regions.

20. Fixed Exterior Shading--Fixed exterior shadings are used for sunlight control to prevent overheating in summer. Methods include attached sun screens and overhang devices. The most effective method for shading south-facing glazing is using an overhang of length ranging between one-fourth (at 36 degrees north latitude) and one-half (at 48 degrees north latitude) of the opening height. Because of the time lag between the sun's movement and seasonal placement of shades, a fixed shading device does not always correspond to the sun's angle. Therefore, it is important to calculate the shade depth that works best throughout the year.

21. Flow Restrictions and Water Conserving Fixtures--Flow and pressure conditions in the piping should be optimum for maximum efficiency in water systems. Reducing water flow and consumption by using flow restrictions and water conserving fixtures may save utility energy by reducing water waste, particularly in buildings such as hospitals and cafeterias, where large amounts of water are consumed. Pump type, size, flow, head capacity, and fixtures, and power consumption under operating conditions should all be evaluated to attain optimum efficiency.

22. Grouping Heat Producing Equipment--By grouping the equipment which produces large amounts of heat, it is possible to have greater control over the heat produced. This heat can either be recycled for use in the building or exhausted to the outside.

23. Heat Absorbing Glazing--Heat absorbing glazing is capable of absorbing selected wavelengths of light. Because heat is absorbed into the glass rather than being reflected, the glass itself will become warm. In more northerly climates, this may be a desirable way of limiting illumination levels while retaining some of the heating qualities of sunlight.

24. Heat Pump Water Heater--Using a heat pump as a heating source for domestic hot water takes advantage of its high-efficiency performance. Since the heat pump provides both heating and cooling capability, it can be used for air-conditioning or refrigeration while heating water. Usually, heat pump systems are only used in small applications of heating and cooling. The energy efficiency ratio (i.e., the ratio of net heating/cooling output to total energy input) is considered to be higher than other systems.

25. Heat Recovery--Energy can be recycled through heat recovery. Heat recovery systems are especially effective for buildings in colder regions that have higher heating needs. The major components of the system are the heat exchanger and a heat storage medium.

26. Heat Recovery Chiller--In refrigeration systems, heat can be recovered from the condenser circuit and used to preheat outside air. Recovered heat may also be used for building space heating systems which use hydronic piping. This system should be considered particularly where coincident cooling and heating loads occur.

27. Humidification of Supply Air--Humidification of supply air increases the energy level (enthalpy) and sensible temperature. In cold climates, comfortable conditions can be achieved at lower air temperature if the supply air is humidified.

28. Increased Ceiling Height--An increased ceiling height can help reduce cooling loads by allowing warm air to rise above the occupied level.

29. Increased Surface Reflectance--Cooling loads may be reduced by increasing the amount of solar radiation reflected from a building's surface. Reflective, light-colored materials should be used. (Note: Although color is a good indication of the ability to reflect solar radiation, it is a poor indicator of the ability to reflect thermal radiation.)

30. Indirect Evaporative Cooling--Indirect evaporative cooling systems use heat recovery units along with water spray units. The heat recovery units lower outside air temperature prior to introduction into the systems. The appropriate air condition level is achieved through a series of cooling, dehumidifying, heating and/or humidifying. These systems are regarded to increase considerably in comfort capacity as well as in efficiency level. However, they are complicated and their costs are high compared to direct systems.

31. Indirect Gain Glazing (Indirect Solar Gain)--Indirect gain systems convert sunlight to heat at an intermediate location (thermal storage) and then release the heat to the space by means of natural radiation and convection processes. The requirements for a thermal storage wall system are south-facing glass areas for maximum winter solar gain and a thermal mass, located 4 in. or more directly behind the glass, which serves for heat storage and distribution. The most appropriate materials for thermal storage are masonry and water.

32. Infiltration Control--Infiltration is air seepage that naturally occurs in and around assemblies of building components. Infiltration control through use of barriers, caulking, insulation, etc., can reduce heating and cooling loads.

33. Insulate Ducts and Pipes--Insulating ducts and pipes saves energy directly. The primary reason for using insulation is to prevent heat loss or gain and to insure that the distribution systems carry the fluid at an appropriate temperature. The heat loss/gain for a given application must be weighed against the cost and energy savings of increased insulation value.

34. Landscaping--Effective use of trees and shrubs can provide protection from potentially harmful site characteristics, such as excessive sun and wind.

35. Latent Heat Exchange Pipe System--Heat exchange pipes are finned tubes (for greater surface area) extending between adjacent air ducts. The tubes run continuously from one duct to the other, and they are on the same horizontal plane. Each tube contains liquid refrigerant which evaporates at the warm end of the tube, absorbing heat from the warm airstream. The evaporated refrigerant then migrates as a gas to the cold end of the tube, where it condenses and releases heat into the cold air stream. The condensed liquid then runs back to the hot end of the tube to complete the cycle.

36. Minimize Glass Area--More energy losses occur through glass than through other building materials. Windows and other glass areas should be minimized to reduce losses; however, the use of glass for light and visual comfort should not be disregarded.

37. Minimize Light Fixtures--Reducing the number of light fixtures to a minimum required level helps prevent overillumination of spaces, saving lighting energy. For certain spaces which require a specific level of illumination, appropriate **daylighting** or **task-specific lighting** should be available.

38. Minimize Resistance in Ducts and Pipes--Simplified ductwork and piping design helps reduce the resistance in a distribution system. Minimum use of bends and joints also lowers the required inner pressure by minimizing the resistance. Lower-pressure ducts or pipes with less resistance may reduce the fan or pump load.

39. Monitor Oxygen in Boiler Combustion Air--In combustion equipment, short oxygen supply results in complete combustion, producing approximately one-third the energy supplied by complete combustion. To avoid this pitfall, it is important to monitor the oxygen level of a boiler's combustion air supply.

40. Motion Sensitive Lighting Controls--Lighting costs can be reduced by turning off the lights when the space is not in use. The adjustments should be automatic since people are usually unreliable for this task. Infrared motion (people) detectors can turn off lights when people have left.

41. Movable Insulation--Movable insulation includes various types of operable insulation devices placed over windows or skylights. The purpose of movable insulation is to reduce heat losses at night. Approximately two-thirds of this heat loss can be prevented by using movable insulation. When using single glazing in cold climates, movable insulation should always be used. To be effective, the insulation must make a well-sealed cover for the glazed opening.

42. Natural Ventilation--Natural ventilation involves proper placement of building openings to effectively use natural breezes of the location to reduce cooling loads.

43. Optimize Insulation Levels--Insulation placed in the roof, walls and floors should provide optimum R-value levels. In the United States, the optimum R-value for roofs ranges between 19 and 38, for walls between 11 and 19, and for floors between 11 and 22, depending on climatic region.

44. Optimum Water Pipe and Tank Insulation--To reduce the loss of utility energy, the hot water circulation and storage systems should be properly insulated. The optimum level of insulation should be determined by considerations of the system, building, and climate conditions.

45. Point-of-Use Water Heaters--Installing water heaters at the point of use--at remote locations or at ones which need larger amounts of hot water--saves both the heat usually lost during circulation and the cost of installing pipes.

46. Preheat Boiler Inlet Water with Flue Gas--Inlet water to a steam boiler must be raised from approximately 70 degrees to the system operating temperature. This temperature difference, and the fuel required to heat the water, can be reduced by reclaiming boiler heat otherwise wasted through the flue to heat the water.

47. Reduced Water Supply Temperature--High temperature domestic hot water requires more heat energy input, and loses more heat during circulation. Maintaining a lower temperature can reduce both initial energy input and circulation loss. Separate water heaters should be available where higher temperature water is needed.

48. Re-use of Exhaust Air--The exhaust air from combustion equipments usually contains unused fuel. Reusing exhaust air increases fuel use efficiency and helps preheat combustion air.

49. Runaround Coil Distribution System--This system is comprised of two or more extended surface fin coils installed in air ducts and interconnected by piping. The coil-type exchanger has the advantage of permitting heat transfer between supply and exhaust systems in widely separated portions of a building, since coils are installed in each of the intake and exhaust ducts, and are connected only by piping.

50. Seasonal Window Shading--Seasonal window shadings use adjustable devices such as operable overhangs, trellised overhangs, or interior shades for shading south-facing glazing. They can be regulated to respond to the seasons or climate. However, they are sometimes difficult to design and maintain, and require the correct seasonal adjustments to be effective.

51. Skylights--Most skylights lie flat in the roof plane and thus accept both direct and diffused sunlight. A skylight can be effective in reducing the lighting loads of buildings with high daytime usage. However, they raise the issue of heat loss, and various controls by orientation or insulation may be needed. Types of skylights include dome or peak, sawtooth, clerestory, and monitors.

52. Spot Cooling and Heating--Spot cooling and heating systems are used for people located far apart. Each requires its own air direction and velocity control.

53. Task-Specific Illumination Level and Equipment--Task-specific illumination systems control the lighting level in each work station. The lighting level depends on considerations such as ceiling height, wall color, number of people in the area, type of work being done, and number of windows. Task lighting works particularly well with an open floor plan.

54. Task-Specific Temperature, Humidity Level--A task-specific temperature and humidity level system provides an appropriate air-conditioning level to each work station. It reduces unnecessary use of energy as well as ensures proper air temperature and humidity levels for specific tasks.

55. Thermal Breaks--Insulation materials increase thermal resistance through the building envelope, but some structural materials made of metal provide conductive energy loss by thermal transmission. The thermal breaks stop the transmission by providing a complete thermal separation between the inner and outer parts of the metal.

56. Timers for Lights--Timers placed on light fixtures can reduce lighting loads by minimizing the time lights stay on when they are not needed.

57. Vapor Barrier--A vapor barrier consists of layers of moisture resisting materials wrapped around ducts or pipes, which provide the necessary degree of vapor sealing to avoid entry of moisture from the surrounding air. It protects ducts or pipes from vapor condensation, which reduces the insulating value of the material. The materials used as vapor barriers should have high moisture resistance. Acceptable materials include sheets of aluminum, reinforced plastic, metal foils, treated papers, and metal jacketing.

58. Variable Air Volume System--A VAV system regulates the amount of air to a given area to match the load, while keeping the air pressure minimized and constant. This system reduces the cooling energy load and the fan horsepower load, as well as air leakage due to low duct pressure.

59. Variable Water Flow Rates--Maintaining uniform water pressure throughout a building requires a high pump load and also causes overuse of water. Providing appropriate water flow rates for water equipment reduces pump motor loads and saves heated water.

60. Vented Roof or Plenum--Providing natural ventilation to roofs and plenums can reduce cooling and fan loads by allowing warm air to escape the building.

61. Zoned Air Handling--In large open areas, it may be advantageous to provide an individual air handling system for each zone. This would eliminate excessive ductwork that would be required of a single system. In addition, if certain areas were not being used, the individual units in those areas could be scheduled off, thus conserving energy. Single zone units also can be arranged to provide spot cooling or heating where zone loads are significant.

62. Zoned Lighting System--Zoned lighting systems control lights in small zones. They can reduce lighting loads by maintaining appropriate levels of illumination for each zone and turning off the unused lights.

APPENDIX B:

ENERGY CONSERVATION OPTION SELECTION MATRICES

MATRIX 1: BUILDING SPACE CHARACTERISTICS

[PRODUCED BY TENNESSEE VALLEY AUTHORITY UNDER CONTRACT TO USA-CERL]

CRITERION	CLASSRM	LAB.	ADMIN. OFFICES	CIR- CULATION	LOUNGE	CAFE- TERIA	LIBRARY	WAREHSE.	GARAGE	COMPUTER ROOM	FLIGHT SIMULTR	BARRACK
DAYTIME USE	8	9	9	9	9	9	8	9	8	8	8	1
NIGHTTIME USE	2	1	1	1	1	1	2	1	2	2	2	9
DIVERSITY	3	7	1	10	8	2	6	10	8	3	3	3
OCCUPANCY LEVEL	10	3	7	3	9	9	2	1	3	5	4	7
OPACITY	6	4	6	8	6	9	2	6	4	1	1	4
HEATING NEED	6	2	7	3	6	5	7	2	2	2	2	8
COOLING NEED	7	2	7	3	6	9	7	1	2	10	8	8
LIGHTING NEED	8	6	8	2	5	5	8	1	6	7	10	3
VENT. NEED	1	5	3	1	1	9	2	1	5	10	10	3
EQUIPMENT NEED	7	8	7	2	7	9	5	1	8	10	10	2
HOT WATER NEED	2	2	2	1	3	10	1	1	2	1	1	4
PROCESS NEED	1	1	1	1	1	10	1	1	1	1	1	2
AIR RATE	200	500	200	300	300	200	0	500	500	0	0	200

MATRICES 2 AND 3: ENERGY CONSERVATION STRATEGY PERFORMANCE ATTRIBUTES
[PRODUCED BY TENNESSEE VALLEY AUTHORITY UNDER CONTRACT TO USA-CERL]

CRITERION		BLDG. ORIENTN.	EARTH BERMING	LAND-SCAPING	DIRECT GAIN GLAZING	INDIRECT GAIN GLAZING	NATURAL VENT.	DAY-LIGHTING	ZONED LIGHTNG. SYSTEM
HEATING DD	>=	500	3500	3000	2000	2000	N/A	1500	N/A
DIURNAL RANGE	<=	N/A	20	N/A	20	20	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	600	N/A	N/A	650	650	N/A	750	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	1000	1000
AV. WIND SPEED	>=	N/A	8	6	N/A	N/A	N/A	N/A	N/A
BEARING		*	N/A	*	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	1000	2000	1000	N/A	N/A	2000	1000	N/A
AV. DAY TEMP	>=	70	75	70	N/A	N/A	70	N/A	N/A
AV. ENTHALPY	<=	N/A	40	N/A	N/A	N/A	35	N/A	N/A
MAX. DAY TEMP	<=	110	100	110	N/A	N/A	82	100	N/A
MEAN DIURNAL RNG	<=	25	30	25	N/A	N/A	25	25	N/A
AV. SOLAR(JUL-SEP)	>=	1000	N/A	1500	N/A	N/A	1500	1500	1500
AV. DAYLIGHT	>=	1000	N/A	N/A	N/A	N/A	N/A	1000	N/A
AV. WIND SPEED	>=	6	8	6	N/A	N/A	7	N/A	N/A
BEARING		*	N/A	*	N/A	N/A	*	N/A	N/A
DAYTIME USE	>=	N/A	N/A	N/A	7	7	6	9	6
NIGHTTIME USE	<=	N/A	N/A	N/A	3	3	4	1	4
DIVERSITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	4	N/A	5	<=4	<=7	<=5	N/A	N/A
OPACITY	>=	5	<=4	5	4	4	4	4	N/A
HEATING NEED	>=	8	8	4	5	5	N/A	N/A	N/A
COOLING NEED	>=	8	<=4	9	<=1	<=1	6	3	5
LIGHTING NEED	>=	5	N/A	6	N/A	N/A	N/A	6	7
EQUIPMENT NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	200	N/A	N/A

CRITERION		INCREASD SURFACE REFLTNCE	TASK SPECIFIC ILLUM. L. & E.	SEASONAL WINDOW SHADING	FIXED EXTERIOR SHADING	DOUBLE GLAZING	MINIMIZE GLASS AREA	SKY-LIGHTS	OPTIMUM INSULTN. LEVEL
HEATING DD	>=	N/A	N/A	750	750	750	2500	N/A	1000
DIURNAL RANGE	<=	N/A	N/A	20	20	N/A	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	750	750	750	N/A	1000	N/A
AV. DAYLIGHT	>=	N/A	N/A	500	500	500	N/A	1000	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	1500	N/A	1000	1000	N/A	1000	N/A	1000
AV. DAY TEMP	>=	75	N/A	70	70	N/A	75	N/A	70
AV. ENTHALPY	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MAX. DAY TEMP	<=	110	N/A	110	110	N/A	110	82	N/A
MEAN DIURNAL RNG	<=	25	N/A	30	30	N/A	25	N/A	N/A
AV. SOLAR(JUL-SEP)	>=	1500	N/A	1500	1500	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	1500	1500	N/A	N/A	1000	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	9	N/A	9	9	N/A	N/A	9	N/A
NIGHTTIME USE	<=	1	N/A	1	1	N/A	N/A	1	N/A
DIVERSITY	>=	N/A	8	N/A	N/A	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	7	N/A	4	4	N/A	N/A	<=3	N/A
OPACITY	>=	N/A	N/A	3	5	2	N/A	1	N/A
HEATING NEED	>=	0	N/A	5	1	7	5	1	7
COOLING NEED	>=	8	6	7	5	2	8	<=1	2
LIGHTING NEED	>=	N/A	6	N/A	N/A	N/A	N/A	7	N/A
EQUIPMENT NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

CRITERION		INFILT-RATION CONTROL	VAPOR BARRIER	AIR BARRIER CURTAINS	AIR DESTRATI-FICATION	INCREASD CEILING HEIGHT	HEAT ABSORBNG GLAZING	MOVABLE INSULATN	THERMAL BREAKS
HEATING DD	>=	1000	750	3500	2500	N/A	N/A	3500	2500
DIURNAL RANGE	<=	15	20	20	N/A	N/A	N/A	20	20
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	N/A	N/A	N/A	N/A	600	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	1000	N/A	500	N/A
AV. WIND SPEED	>=	6	6	8	N/A	N/A	N/A	9	7
BEARING		*	*	*	N/A	N/A	N/A	*	N/A
COOLING DD	>=	1000	1500	N/A	1000	1000	1000	1500	N/A
AV. DAY TEMP	>=	75	80	N/A	75	80	70	85	N/A
AV. ENTHALPY	<=	40	40	N/A	N/A	N/A	N/A	N/A	40
MAX. DAY TEMP	<=	110	110	N/A	110	110	110	100	110
MEAN DIURNAL RNG	<=	N/A	N/A	N/A	N/A	25	30	30	N/A
AV. SOLAR(JUL-SEP)	>=	N/A	N/A	N/A	N/A	N/A	1500	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	1000	N/A	N/A	N/A
AV. WIND SPEED	>=	6	8	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		*	*	*	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	N/A	N/A	N/A	N/A	N/A	10	5	N/A
NIGHTTIME USE	<=	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A
DIVERSITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	N/A	N/A	N/A	5	7	8	5	N/A
OPACITY	>=	2	N/A	4	N/A	N/A	4	6	5
HEATING NEED	>=	7	7	9	5	2	0	9	9
COOLING NEED	>=	5	4	1	7	7	6	<=3	<=2
LIGHTING NEED	>=	N/A	N/A	N/A	N/A	5	<=1	N/A	N/A
EQUIPMENT NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	N/A	6	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AIR RATE	<=	N/A	N/A	N/A	300	N/A	N/A	N/A	N/A

CRITERION		LATENT HEAT EXCHANGE PIPE SYSTEM	TASK SPECIFIC TEMP. & HUMIDITY LEVEL	ZONED AIR HANDLNG. SYSTEM	SPOT COOLING AND HEATING	MINIMIZE RES. IN DUCT & PIPE	INSULATE DUCTS & PIPES	VARIABLE WATER FLOW RATES	DIRECT EVAPORTV COOLING
HEATING DD	>=	N/A	500	500	500	500	1500	500	N/A
DIURNAL RANGE	<=	N/A	N/A	N/A	20	N/A	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	750	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	1500	1000	1000	1500	1500	1000	1500	2000
AV. DAY TEMP	>=	75	70	N/A	80	70	75	80	80
AV. ENTHALPY	<=	35	N/A	N/A	N/A	N/A	40	N/A	25
MAX. DAY TEMP	<=	110	N/A	N/A	90	N/A	110	N/A	100
MEAN DIURNAL RNG	<=	30	N/A	N/A	30	N/A	30	N/A	N/A
AV. SOLAR(JUL-SEP)	>=	N/A	N/A	N/A	1500	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	N/A	N/A	5	N/A	N/A	N/A	N/A	6
NIGHTTIME USE	<=	N/A	N/A	5	N/A	N/A	N/A	N/A	4
DIVERSITY	>=	N/A	N/A	N/A	7	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	6	10	N/A	3	N/A	6	6	3
OPACITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2
HEATING NEED	>=	N/A	3	4	5	5	9	N/A	N/A
COOLING NEED	>=	5	4	4	3	5	9	N/A	8
LIGHTING NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EQUIPMENT NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	3	5	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	5	N/A	5	5	7	N/A	N/A
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	300

CRITERION		VENTED ROOF OR PLENUM	GROUP HEAT-PRODUCNG EQUIP.	AIRLOCK ENTRIES	DUTY CYCLING	VAV AIRSIDE SYSTEM	DECRSD SUPPL & M.U. AIR	AIR TO AIR HEAT EXCHNGR
HEATING DD	>=	N/A	2500	2500	3500	500	3500	750
DIURNAL RANGE	<=	N/A	20	20	N/A	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	N/A	N/A	750	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	7	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	*	N/A	N/A	N/A	N/A
COOLING DD	>=	1000	2000	N/A	1500	1000	1500	1500
AV. DAY TEMP	>=	70	80	80	75	75	75	75
AV. ENTHALPY	<=	40	N/A	40	N/A	35	N/A	35
MAX. DAY TEMP	<=	110	110	110	N/A	110	N/A	110
MEAN DIURNAL RNG	<=	N/A	N/A	N/A	N/A	30	25	30
AV. SOLAR(JUL-SEP)	>=	1000	N/A	N/A	N/A	1500	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	6	N/A	6	N/A	N/A	N/A	N/A
BEARING		*	N/A	*	N/A	N/A	N/A	N/A
DAYTIME USE	>=	7	N/A	N/A	N/A	N/A	N/A	N/A
NIGHTTIME USE	<=	3	N/A	N/A	N/A	N/A	N/A	N/A
DIVERSITY	>=	N/A	N/A	8	N/A	9	2	N/A
OCCUPANCY LEVEL	>=	7	8	7	5	8	N/A	6
OPACITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HEATING NEED	>=	0	3	8	N/A	2	6	5
COOLING NEED	>=	9	7	4	5	6	5	5
LIGHTING NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EQUIPMENT NEED	>=	N/A	9	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	5	N/A	N/A	8	6	7	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	7	N/A	6	N/A	N/A	5
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A

CRITERION		MOTION SENSTVE LIGHTING CONTROL	HEAT PUMP WATER HEATER	HEAT RECOVERY	POINT OF USE WATER HEATERS	OPTIMUM W. PIPE & TANK INSULTN LEVEL	EMCS	REDUCED WATER SUPPLY TEMP.	FLOW RESTRCTN & WATER CONSRVNG FIXTURES
HEATING DD	>=	N/A	N/A	4000	N/A	1500	4000	N/A	N/A
DIURNAL RANGE	<=	N/A	N/A	N/A	N/A	N/A	20	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	3000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAY TEMP	>=	85	N/A	N/A	N/A	N/A	80	N/A	N/A
AV. ENTHALPY	<=	N/A	N/A	N/A	N/A	40	N/A	N/A	N/A
MAX. DAY TEMP	<=	N/A	110	N/A	N/A	110	N/A	N/A	N/A
MEAN DIURNAL RNG	<=	N/A	N/A	N/A	N/A	25	N/A	N/A	N/A
AV. SOLAR(JUL-SEP)	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NIGHTTIME USE	<=	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DIVERSITY	>=	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A
OPACITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HEATING NEED	>=	N/A	<=1	10	N/A	2	7	N/A	N/A
COOLING NEED	>=	6	7	N/A	N/A	4	7	N/A	N/A
LIGHTING NEED	>=	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EQUIPMENT NEED	>=	N/A	N/A	6	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	8	5	5	9	5	10	10
PROCESS NEED	>=	N/A	7	6	5	<=9	N/A	8	2
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

CRITERION		HUMIDFCN OF SUPPLY AIR	RUN-AROUND COIL DISTRBTN SYSTEM	MINIMIZE LIGHT FIXTURES	EFFCNT FIXTRS & LAMPS	EFFICNT ARTIFCL LIGHTS COMPTBLE W/DLIGHT	TIMERS FOR LIGHTS	DAYLIGHT RESPNSVE LIGHTING CONTROL
HEATING DD	>=	3000	3500	N/A	N/A	N/A	N/A	N/A
DIURNAL RANGE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	N/A	N/A	750	N/A	750
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	1000	1000	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	N/A	N/A	3000	1500	N/A	N/A	N/A
AV. DAY TEMP	>=	N/A	N/A	85	70	N/A	N/A	N/A
AV. ENTHALPY	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MAX. DAY TEMP	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEAN DIURNAL RNG	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. SOLAR(JUL-SEP)	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	1500	N/A	1500
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	N/A	N/A	N/A	N/A	9	5	9
NIGHTTIME USE	<=	N/A	N/A	N/A	N/A	1	5	1
DIVERSITY	>=	N/A	N/A	N/A	N/A	N/A	2	N/A
OCCUPANCY LEVEL	>=	5	6	N/A	N/A	N/A	N/A	N/A
OPACITY	>=	N/A	N/A	N/A	N/A	4	N/A	4
HEATING NEED	>=	7	8	<=1	<=1	N/A	<=1	N/A
COOLING NEED	>=	N/A	7	6	6	7	6	7
LIGHTING NEED	>=	N/A	N/A	7	8	6	7	6
EQUIPMENT NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	8	N/A	N/A	N/A	N/A	N/A
PROCESS NEED	>=	N/A	8	N/A	N/A	N/A	N/A	N/A
AIR RATE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A

CRITERION		INDIRECT EVAPORTV COOLING	EXTERIOR V_NTING HEATPROD EQUIP.	DRY-BULB TEMP. ECONOMY COOLING	REUSE OF EXHAUST AIR	ELECTRNC FILTER	HEAT RECOVERY CHILLER	MONITOR OXYGEN IN BOILER COMB.AIR	PREHEAT BOILER INLET WATER W/ FLUE GAS
HEATING DD	>=	N/A	N/A	1000	3000	500	3000	2000	4000
DIURNAL RANGE	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. SOLAR(DEC-MAR)	<=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COOLING DD	>=	2000	1500	1500	N/A	1000	1500	N/A	N/A
AV. DAY TEMP	>=	80	75	70	N/A	N/A	80	N/A	N/A
AV. ENTHALPY	<=	25	N/A	35	N/A	N/A	N/A	N/A	N/A
MAX. DAY TEMP	<=	100	110	85	N/A	N/A	N/A	N/A	N/A
MEAN DIURNAL RNG	<=	N/A	N/A	25	N/A	N/A	N/A	N/A	N/A
AV. SOLAR(JUL-SEP)	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. DAYLIGHT	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AV. WIND SPEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BEARING		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DAYTIME USE	>=	N/A	N/A	5	N/A	N/A	N/A	N/A	N/A
NIGHTTIME USE	<=	N/A	N/A	5	N/A	N/A	N/A	N/A	N/A
DIVERSITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OCCUPANCY LEVEL	>=	3	N/A	5	2	8	N/A	N/A	N/A
OPACITY	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HEATING NEED	>=	N/A	0	N/A	6	5	7	7	6
COOLING NEED	>=	9	9	5	0	5	N/A	N/A	N/A
LIGHTING NEED	>=	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EQUIPMENT NEED	>=	N/A	9	N/A	N/A	N/A	N/A	N/A	N/A
FAN NEED	<=	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A
HOT WATER NEED	<=	N/A	N/A	N/A	N/A	N/A	5	6	7
PROCESS NEED	>=	N/A	8	N/A	5	N/A	4	6	7
AIR RATE	<=	200	N/A	200	N/A	N/A	N/A	N/A	N/A

Table B1

Energy Conservation Option Variables

Space Types		
1. Classroom	5. Lounge	9. Garage
2. Laboratory	6. Cafeteria	10. Computer Room
3. Office	7. Library	11. Flight Simulator
4. Circulation	8. Warehouse	12. Barrack

Space Dependent Criteria

1. Daytime use	6. Heating need	11. Hot water need
2. Nighttime use	7. Cooling need	12. Process need
3. Diversity	8. Lighting need	13. Design air rate
4. Occupancy level	9. Equipment need	
5. Opacity of envelope	10. Fan need	

Weather Criteria

1. Heating degree days	6. Winter wind bearing	11. Summer mean diurnal range
2. Winter diurnal range	7. Cooling degree days	12. Summer average solar
3. Winter average solar	8. Summer average daytime temp.	13. Summer average daylight
4. Winter average daylight	9. Summer average enthalpy	14. Summer average wind speed
5. Winter average wind speed	10. Summer maximum daytime temp.	15. Summer wind bearing

APPENDIX C:

CATEGORIZATION OF ENERGY CONSERVATION OPTIONS

General Options Categories*

1. Site Strategies
2. Building Shell Strategies for Heating
3. Air Circulation Strategies
4. HVAC Heating Equipment Strategies
5. HVAC Heating System Strategies
6. Building Shell Strategies for Cooling
7. Circulation Space Strategies
8. HVAC Cooling Equipment Strategies
9. HVAC Cooling System Strategies
10. Ventilation Strategies
11. Building Shell Strategies for Lighting
12. Lighting Equipment Strategies
13. Lighting Control Strategies
14. Whole Building Strategies

Heating, Cooling, Ventilation, Lighting, or Whole Building Categories

Heating Strategies

1. Site Strategies

   a) Building Shape and Orientation**
   b) Earth Berming
   c) Landscaping

2. Building Shell Strategies

   a) Direct Gain Glazing
   b) Double Glazing
   c) Indirect Gain Glazing
   d) Infiltration Control
   e) Minimize Glass Area
   f) Movable Insulation
   g) Optimize Insulation Levels
   h) Thermal Breaks

3. Air Circulation Strategies

   a) Air Barrier Curtains
   b) Airlock Entries

*Use with tables in Appendix D.
**Descriptions of strategies are listed alphabetically in Appendix A.

4. HVAC Heating Equipment Strategies

a) Air-to-Air Heat Exchangers
b) Insulate Ducts and Pipes
c) Latent Heat Exchange Pipe System
d) Minimize Resistance in Ducts and Pipes
e) Monitor Oxygen in Boiler Combustion Air
f) Preheat Boiler Inlet Water with Flue Gas

5. HVAC Heating System Strategies

a) Air Destratification
b) Decreased Supply and Make-up Air
c) Duty Cycling
d) Electronic Filters
e) Energy Monitoring Control System
f) Heat Recovery
g) Humidification of Supply Air
h) Re-use of Exhaust Air
i) Runaround Coil Distribution System
j) Spot [Cooling and] Heating
k) Task-Specific Temperature and Humidity Level
l) Variable Air Volume Systems
m) Zoned Air Handling

Cooling Strategies

6. Building Shell Strategies for Cooling

a) Fixed Exterior Shading
b) Heat Absorbing Glazing
c) Increased Ceiling Height
d) Increased Surface Reflectance
e) Infiltration Control
f) Minimize Glass Area
g) Seasonal Window Shading
h) Thermal Breaks

7. Circulation Space Strategies

a) Air Barrier Curtains
b) Airlock Entries

8. HVAC Cooling Equipment Strategies

a) Exterior Venting of Heat Producing Equipment
b) Grouping Heat Producing Equipment
c) Minimize Resistance in Ducts and Pipes

9. HVAC Cooling System Strategies

a) Air Destratification
b) Decreased Supply and Makeup Air
c) Direct Evaporative Cooling

d) Dry Bulb Temperature Economy Cooling
e) Electronic Filters
f) Energy Monitoring and Control System
g) Heat Recovery Chiller
h) Indirect Evaporative Cooling
i) Runaround Coil Distribution System
j) Spot Cooling [and Heating]
k) Variable Water Flow Rates
l) Variable Air Volume System
m) Task-Specific Temperature and Humidity Levels
n) Zoned Air Handling

Ventilation Strategies

10. Ventilation Strategies

a) Natural Ventilation
b) Vented Roof or Plenum

Lighting Strategies

11. Building Shell Strategies for Lighting

a) Daylighting
b) Direct Gain Glazing
c) Indirect Gain Glazing
d) Skylights

12. Lighting Equipment Strategies

a) Efficient Artificial Lights Compatible with Daylight
b) Efficient Fixtures and Lamps
c) Minimize Light Fixtures
d) Task-Specific Illumination Level and Equipment
e) Zoned Lighting System

13. Lighting Controls Strategies

a) Daylight Responsive Lighting Controls
b) Duty Cycling
c) Motion Sensitive Lighting Controls
d) Timers for Lights

14. Whole Building Strategies

a) Flow Restrictions and Water Conserving Fixtures
b) Heat Pump Water Heater
c) HVAC Equipment Strategies
d) HVAC System Strategies
e) Optimize Insulation Levels
f) Optimum Water Pipe and Tank Insulation
g) Point-of-Use Water Heaters
h) Reduced Water Supply Temperature
i) Vapor Barrier

APPENDIX D:

CONSOLIDATED SELECTION MATRICES

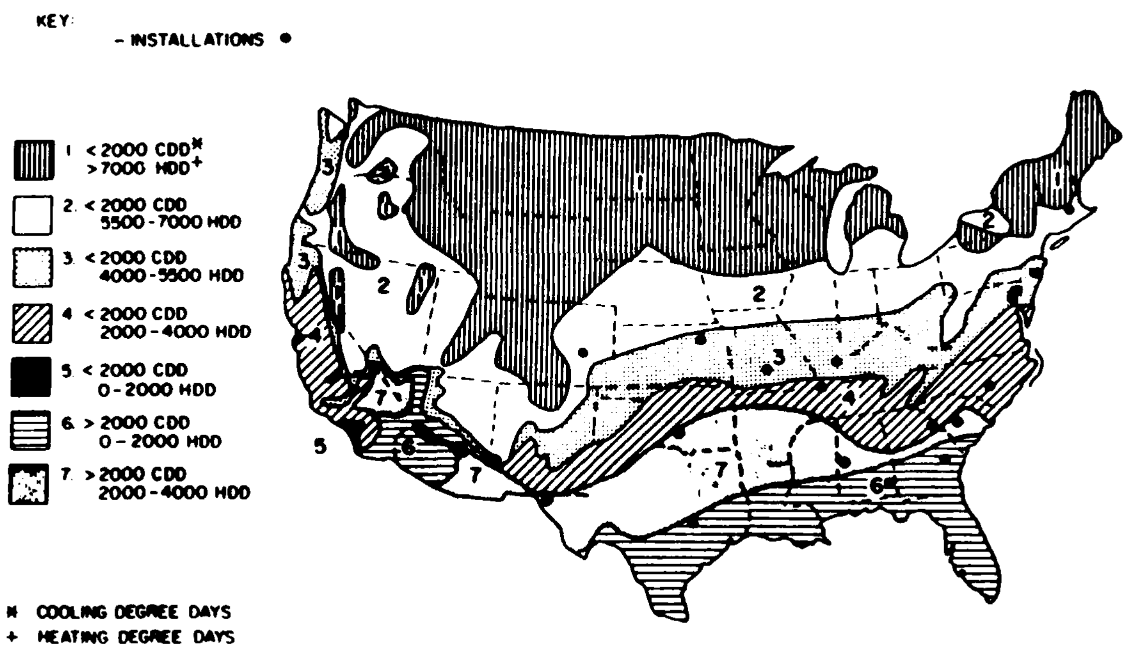

Figure D1. Army climatic regions.

Table D1

Energy Loads Matrix by Region and Space Type

REGION / SPACE TYPE	1	2	3	4	5	6	7
CLASSROOM	H-L	H-L	H-L	L-H	L-C	C-L	L-C
LABORATORY	H-L	H-L	H-L	L-H	L-C	C-L	L-C
OFFICE	H-L	H-L	H-L	L-H	L-C	C-L	L-C
CIRCULATION	H-L	H-L	H-C	C-H	C-L	C-L	C-L
LOUNGE	H-L	H-L	H-C	C-H	C-L	C-L	C-L
CAFETARIA	H-L	H-L	C-L	C-L	C-L	C-L	C-L
LIBRARY	H-L	H-L	H-L	L-C	L-C	C-L	C-L
WAREHOUSE	H-L	H-L	H-L	H-L	L-V	L-V	L-V
GARAGE	H-L	H-L	H-L	H-L	L-V	L-V	L-V
COMPUTER ROOM	C-L	C-L	C-L	C-L	C-L	C-L	C-L
FLIGHT SIMULATOR	C-L	C-L	C-L	C-L	C-L	C-L	C-L
BARRACK	H-L	H-L	H-C	H-C	C-H	C-L	C-L
MEDICAL FACILITY	H-L	H-L	H-L	H-C	C-H	C-L	C-L

H = HEATING LOAD C = COOLING LOAD
L = LIGHTING LOAD V = VENTILATION LOAD

Note: See Appendix E for listing of Army installations and their corresponding Army climatic regions.

Table D2

Strategy Category Matrix by Region and Space Type

REGION / SPACE TYPE		1	2	3	4	5	6	7
CLASSROOM	P S	2,14 11,12	2,14 11,12	2,14 11,12	11,12 2,14	11,12 6,14	6,14 11,12	11,12 6,14
LABORATORY	P S	4, 5 12,13	4, 5 12,13	4, 5 12,13	12,13 4, 5	12,13 8, 9	8, 9 12,13	12,13 8, 9
OFFICE	P S	2, 5 11,12	2, 5 11,12	2, 5 11,12	11,12 2, 5	11,12 6, 9	6, 9 11,12	11,12 6, 9
CIRCULATION	P S	3 12	3 12	3 7	7 3	7 12	7 12	7 12
LOUNGE	P S	4, 5 12,13	4, 5 12,13	4, 5 8, 9	8, 9 4, 5	8, 9 12,13	8, 9 12,13	8, 9 12,13
CAFETARIA	P S	4, 5 11,12	4, 5 11,12	8, 9 11,12	8, 9 11,12	8, 9 11,12	8, 9 11,12	8, 9 11,12
LIBRARY	P S	2, 5 11,12	2, 5 11,12	2, 5 11,12	11,12 6, 9	11,12 6, 9	6, 9 11,12	6, 9 11,12
WAREHOUSE	P S	1,14 12,13	1,14 12,13	1,14 12,13	1,14 12,13	12,13 10	12,13 10	12,13 10
GARAGE	P S	1,14 12,13	1,14 12,13	1,14 12,13	1,14 12,13	12,13 10	12,13 10	12,13 10
COMPUTER ROOM	P S	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13
FLIGHT SIMULATOR	P S	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13	8, 9 12,13
BARRACK	P S	2,14 11,12	2,14 11,12	2,14 6, 9	2,14 6, 9	6, 9 2,14	6, 9 11,12	6, 9 11,12
MEDICAL FACILITY	P S	4, 5 12,13	4, 5 12,13	4, 5 12,13	4, 5 8, 9	8, 9 4, 5	8, 9 12,13	8, 9 12,13

P = PRIMARY LOAD STRATEGIES S = SECONDARY LOAD STRATEGIES

Note: Numbers refer to the stategy categories identified in Appendix C.

APPENDIX E:

POTENTIAL ENERGY SAVINGS FIGURES BY SPACE TYPE AND INSTALLATION

POTENTIAL ENERGY SAVINGS FIGURES BY SPACE TYPE AND INSTALLATION

INSTALLATION	STATE	ARMY REGION	DOE REGION	ENERGY COST [$/KBTU]	SPACE TYPE: CLASS.	LAB.	[$/SF] FIGURES OFFICE	LOUNGE	CAFE.	LIBRARY	WAREHOUSE	GARAGE	COMPUTER	FLIGHT S.	BARRACKS	MEDICAL
Aberdeen PG	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Alianamu Mil Res	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Anniston AD	AL	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Arl Hall Sta	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Army MAMR Ctr	MA	2	1	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.69	$1.49
Camp Atterbury	IN	3	5	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.53	$1.08
Badger AAP	WI	1	5	0.018	$0.18	$0.18	$0.45	$0.21	$0.27	$0.18	$0.32	$0.32	$0.18	$0.18	$0.54	$1.17
Bayonne MOT	NJ	3	2	0.023	$0.23	$0.11	$0.45	$0.00	$0.27	$0.23	$0.34	$0.34	$0.11	$0.23	$0.67	$1.36
Wm Beaumont AMC	TX	7	6	0.017	$0.17	$0.09	$0.34	$0.05	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Ft Belvoir	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft Benning	GA	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Bliss	TX	4	6	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.03
Boston DefSupActy	MA	2	1	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.69	$1.49
Ft Bragg	NC	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Cameron Station	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ft Campbell	KY	3	4	0.017	$0.17	$0.09	$0.34	$0.00	$0.20	$0.17	$0.26	$0.26	$0.09	$0.17	$0.50	$1.02
Carlisle Barracks	PA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft Carson	CO	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
Ft Chaffee	AR	7	6	0.017	$0.17	$0.09	$0.34	$0.05	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Cold Regions Lab	NH	1	1	0.023	$0.23	$0.23	$0.57	$0.27	$0.34	$0.23	$0.40	$0.40	$0.23	$0.23	$0.69	$1.49
Cornhusker AAP	NB	2	7	0.019	$0.19	$0.19	$0.49	$0.14	$0.29	$0.29	$0.34	$0.34	$0.19	$0.29	$0.58	$1.26
Corpus Christi AD	TX	6	6	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.86
Crane AAAct	IN	3	5	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.53	$1.08
Def Const Sup Ctr	OH	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Def Fuel Sup Pt	OH	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Def Gen Suppt Ctr	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Def Mapping Agcy	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft Derussy	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Ft Detrick	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Detroit Arsenal	MI	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Ft Devens	MA	2	1	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.69	$1.49
Harry Diamond Lab	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft Dix	NJ	3	2	0.023	$0.23	$0.11	$0.45	$0.00	$0.27	$0.23	$0.34	$0.34	$0.11	$0.23	$0.67	$1.36
Ft Douglas	UT	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
Ft Drum	NY	1	2	0.023	$0.23	$0.23	$0.57	$0.26	$0.34	$0.23	$0.40	$0.40	$0.23	$0.23	$0.68	$1.47
Dugway PG	UT	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
Ft Eustis	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Fitzsimmons AMC	CO	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
Ft Gillem	GA	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Gordon	GA	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Greely	AK	1	6	0.017	$0.17	$0.17	$0.43	$0.20	$0.26	$0.17	$0.30	$0.30	$0.17	$0.17	$0.51	$1.12
Ft Hamilton	NY	3	2	0.023	$0.23	$0.11	$0.45	$0.00	$0.27	$0.23	$0.34	$0.34	$0.11	$0.23	$0.67	$1.36
Ft Ben Harrison	IN	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Hawthorne AAP	NV	2	9	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Helemano Mil Res	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Hickam Army Field	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.0C	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Ft A P Hill	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft Hood	TX	6	6	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.86
Ft Sam Houston	TX	6	6	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.86
Ft Huachuca	AZ	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Hunter Army A F	GA	7	4	0.017	$0.17	$0.09	$0.34	$0.05	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.32	$1.02
Indiana AAP	IN	3	5	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.53	$1.08
Ft Indiantown Gap	CA	2	9	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Iowa AAP	IA	2	7	0.019	$0.19	$0.19	$0.49	$0.14	$0.29	$0.29	$0.34	$0.34	$0.19	$0.29	$0.58	$1.26
Ft Irwin	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ft Jackson	SC	7	4	0.017	$0.17	$0.09	$0.34	$0.05	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.32	$1.02
Jefferson P G	IN	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17

Joliet AAP	IL	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Kansas AAP	KS	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Ft Knox	KY	3	4	0.017	$0.17	$0.09	$0.34	$0.00	$0.20	$0.17	$0.26	$0.26	$0.09	$0.17	$0.50	$1.02
Lake City	MO	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Ft Leavenworth	KS	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Ft Lee	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Letterkenny AD	PA	2	3	0.018	$0.18	$0.18	$0.46	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Letterman AMC	CA	7	9	0.018	$0.18	$0.09	$0.36	$0.08	$0.27	$0.36	$0.32	$0.32	$0.09	$0.27	$0.38	$1.09
Ft Lewis	WA	3	10	0.008	$0.08	$0.04	$0.16	$0.00	$0.09	$0.08	$0.12	$0.12	$0.04	$0.08	$0.23	$0.47
Lex-Blue GrassACT	KY	3	4	0.017	$0.17	$0.09	$0.34	$0.00	$0.20	$0.17	$0.26	$0.26	$0.09	$0.17	$0.50	$1.02
Ft Hunter Liggett	CA	3	9	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Lima Army Mod Ctr	OH	2	8	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Lone Star AAP	TX	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Longhorn AAP	TX	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Louisiana AAP	LA	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Madigan AMC	WA	8	10	0.008	$0.04	$0.04	$0.04	$0.00	$0.09	$0.04	$0.08	$0.08	$0.04	$0.08	$0.15	$0.40
MA Inst Tech Rsch	MA	2	1	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.69	$1.49
McAlester AAP	OK	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Ft McClellan	AL	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft McCoy	WI	1	8	0.018	$0.18	$0.18	$0.48	$0.21	$0.27	$0.18	$0.32	$0.32	$0.18	$0.18	$0.54	$1.17
Ft McNair	DC	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ft McPherson	GA	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Meade	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Memphis Def Depot	TN	7	4	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.32	$1.02
Michigan AAP	MI	2	8	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Milan AAP	TN	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Monmouth	NJ	3	2	0.023	$0.23	$0.11	$0.45	$0.00	$0.27	$0.23	$0.34	$0.34	$0.11	$0.23	$0.67	$1.36
Ft Monroe	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Presidio Montery	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ft Myer	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Natick ResDev Ctr	MA	2	1	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.69	$1.49
Navajo Army Depot	AZ	1	9	0.018	$0.18	$0.18	$0.48	$0.21	$0.27	$0.18	$0.32	$0.32	$0.18	$0.18	$0.55	$1.18
New Cumberland AD	PA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Newport AAP	IN	3	8	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.53	$1.08
Oakdale Sup Dst	PA	2	3	0.018	$0.18	$0.18	$0.46	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Oakland Army Base	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ogden Def Depot	UT	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
Ft Ord	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Camp Parks	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Picatinny Arsenal	NJ	2	2	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.68	$1.47
Ft Pickett	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Pine Bluff Ars	AR	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Ft Polk	LA	6	6	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.86
Pueblo Depot Act	CO	3	8	0.016	$0.16	$0.08	$0.32	$0.00	$0.19	$0.16	$0.24	$0.24	$0.08	$0.16	$0.47	$0.96
Radford AAP	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Ravenna AAP	OH	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Red River AD	TX	7	6	0.017	$0.17	$0.09	$0.34	$0.08	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Redstone Arsenal	AL	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Richardson	AK	1	10	0.008	$0.08	$0.08	$0.20	$0.09	$0.12	$0.08	$0.14	$0.14	$0.08	$0.08	$0.24	$0.51
Richmond Army Dep	VA	4	3	0.018	$0.36	$0.09	$0.27	$0.02	$0.26	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ft Riley	KS	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Ft Ritchie	MD	2	3	0.018	$0.18	$0.18	$0.46	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Riverbank AAP	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Camp Roberts	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Rock Island Ars	IL	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Rocky Mt Arsenal	CO	2	8	0.026	$0.26	$0.26	$0.65	$0.19	$0.39	$0.39	$0.46	$0.46	$0.26	$0.39	$0.78	$1.69
Ft Rucker	AL	6	4	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.85
Sacramento AD	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
St Louis Sup Ctr	IL	3	5	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.53	$1.08
Presidio San Fran	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Savanna AD	IL	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Schofield Bks	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Scranton AAP	PA	2	3	0.018	$0.18	$0.18	$0.46	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Seneca AD	NY	2	2	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.68	$1.47

Ft Shafter	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Sharpe AD	CA	4	9	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.55	$1.09
Ft Sheridan	IL	2	5	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.54	$1.17
Sierra AD	CA	2	9	0.018	$0.18	$0.18	$0.45	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Ft Sill	OK	7	6	0.017	$0.17	$0.09	$0.34	$0.05	$0.26	$0.34	$0.30	$0.30	$0.09	$0.26	$0.33	$1.03
Ft Stewart	GA	6	4	0.017	$0.00	$0.09	$0.09	$0.00	$0.29	$0.09	$0.17	$0.17	$0.09	$0.09	$0.36	$0.86
Ft Story	VA	4	5	0.018	$0.36	$0.09	$0.27	$0.02	$0.25	$0.18	$0.27	$0.27	$0.09	$0.36	$0.54	$1.08
Sunflower AAP	KS	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Sunny Point MOT	NC	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Tobyhanna AD	PA	2	3	0.018	$0.18	$0.18	$0.46	$0.13	$0.27	$0.27	$0.32	$0.32	$0.18	$0.27	$0.55	$1.18
Tooele AD	UT	2	8	0.016	$0.16	$0.16	$0.40	$0.12	$0.24	$0.24	$0.28	$0.28	$0.16	$0.24	$0.48	$1.04
USA Topo Ctr	MD	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Tripler AMC	HI	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91
Twin Cities AAP	MN	1	5	0.018	$0.18	$0.18	$0.45	$0.21	$0.27	$0.18	$0.32	$0.32	$0.18	$0.18	$0.54	$1.17
Umatilla Dpt Act	OR	3	10	0.008	$0.08	$0.04	$0.16	$0.00	$0.09	$0.08	$0.12	$0.12	$0.04	$0.08	$0.23	$0.47
U S Mil Academy	NY	2	2	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.68	$1.47
Vint Hill F Sta	VA	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Volunteer AAP	TN	4	4	0.017	$0.34	$0.09	$0.26	$0.02	$0.24	$0.17	$0.26	$0.26	$0.09	$0.34	$0.51	$1.02
Ft Wainwright	AK	1	6	0.017	$0.17	$0.17	$0.43	$0.20	$0.26	$0.17	$0.30	$0.30	$0.17	$0.17	$0.51	$1.12
Walter Reed AMC	DC	3	3	0.018	$0.18	$0.09	$0.36	$0.00	$0.22	$0.18	$0.27	$0.27	$0.09	$0.18	$0.54	$1.09
Watervliet Ars	NY	2	2	0.023	$0.23	$0.23	$0.57	$0.17	$0.34	$0.34	$0.40	$0.40	$0.23	$0.34	$0.68	$1.47
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Ft Wingate	NM	2	6	0.017	$0.17	$0.17	$0.43	$0.13	$0.26	$0.26	$0.30	$0.30	$0.17	$0.26	$0.51	$1.12
Ft Leonard Wood	MO	3	7	0.019	$0.19	$0.10	$0.39	$0.00	$0.23	$0.19	$0.29	$0.29	$0.10	$0.19	$0.57	$1.16
Yakima Firing Ctr	WA	2	10	0.008	$0.08	$0.08	$0.20	$0.06	$0.12	$0.12	$0.14	$0.14	$0.08	$0.12	$0.24	$0.51
Yuma PG	AZ	6	9	0.018	$0.00	$0.09	$0.09	$0.00	$0.31	$0.09	$0.18	$0.18	$0.09	$0.09	$0.38	$0.91

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AEI	Architectural/Engineering Instructions
AFM	Air Force Manual
AR	Army Regulation
A/E	architecture and engineering
BLAST	Building Loads Analysis and System Thermodynamics
BY	budget year
CY	construction year
DA	Department of the Army
DD	Department of Defense (form)
DEH	Directorate of Engineering and Housing
DHW	domestic hot water
DY	design year
DOD	Department of Defense
DOE	Department of Energy
ETL	Engineering Technical Letter
GY	guidance year
HQDA	Headquarters, Department of the Army
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	heating, ventilating, and air-conditioning
LBL	Lawrence Berkeley Laboratory
MACOM	Major Command
MCA	Military Construction, Army
NAVFAC P	Naval Facilities Engineering Command Publication
NSC	National Security Council
OCE	Office of the Chief of Engineers
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PDB	Project Development Brochure
PROSPECT	Proponent Sponsored Engineer Corps Training
S&A	Supervision and administration
SRP	Special Requirements Paragraph
TM	(Army) Technical Manual
TRADOC	Training and Doctrine Command
TVA	Tennessee Valley Authority
T^3B	Technology Transfer Test Bed
USA-CERL	U.S. Army Construction Engineering Research Laboratory
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